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OF THE UNIVERSITY OF CHICAGO

Voluntary Isolation of Control in a Natural Muscle Group

By

JASPER CONVERSE BARNES, Ph.D.
Professor of Psychology, Maryville College

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Owing to loss of proof-sheets the issue of Psychological Monograph No. 91 has been considerably delayed. The title page and table of contents of Vol. 21 will be sent out with Monograph No. 91.

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PREFACE

I take this opportunity to express my keen sense of obligation to my many friends whose help has made it possible for me to write this paper. Especially to my teachers, Professor James Rowland Angell, Professor John B. Watson, now of Johns Hopkins University, Professor George B. Mead, and Professor Edward S. Ames, I owe much for their stimulating instruction and timely encouragement. Professor Harvey Carr gave me valuable suggestions as to the construction of apparatus.

I am also much indebted to my laboratory assistants, Mr. George H. Payne, Mr. Mark H. May, and Mr. George W. Middleton, who served in double capacity, as subjects, and, in the tests on the writer, as experimenters. To the students and teachers who gave so much of their time in serving as reagents in my experiments, I am particularly grateful.

My wife has given me great assistance in the reading, translating, and interpreting both German and French literature, treating of the problems discussed in the following pages.

J. C. B.

Maryville College, August 15, 1912.

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INTRODUCTION

Statement of Problem

The investigation recorded in this paper was begun in the fall of 1909 and was continued through the academic years of 1909-1911 and the summer of 1910. Publication of the results has been unfortunately delayed. It was hoped that by a long series of tests involving a careful examination of the voluntary control processes of the movement of the ring finger in both vertical and horizontal planes, and by a careful investigation of the inhibitory processes of the other fingers, some additional light might be cast both upon the problem of voluntary control of movement and upon the nature of the process of inhibition. The problem involved the determination of the mental antecedents of the movement, the mental concomitants which controlled it and the nature of the psychical processes involved in inhibition. The working out of these problems raised questions as to the nature of automatic action and imageless thought.

Previous experimenters have studied the growth of control in muscles over which normally we have little or no mastery, like the muscles of the external ear; or the methods of gaining new dexterities like type-writing with muscles over which we have a high degree of control. The present experiments differentiate themselves from both the preceding cases in dealing with the isolation of control over special muscles in a group which ordinarily contract together. Movement of the ring finger tends strongly to carry with it movement of the adjacent fingers. Our procedure, as will be seen, involves the suppression of the movement of these neighboring fingers and the development of the coordinations of the ring finger alone.

As the solution of our problem depended largely upon the introspective reports of the subjects who acted as reagents in the experiments, it was thought best to select persons who had had work in psychology. The persons serving as subjects were either instructors, graduate students in psychology, or senior college students that had taken one or more courses in the department. Twenty-two men and ten women were used and it may be said at once that no characteristic sex differences appear in the results.

In general outline the experiments fell into four series. In the first series, movement went on without any instruction as to method and without any limitation of the governing senses. Tests of the voluntary control of the fourth, or ring finger, of right and left hands were made for both vertical and lateral movements.

In the second series of experiments, movement was accompanied by a limiting or distracting process. This distracting process consisted in (1) the use of the blindfold; (2) counting aloud blindfolded; (3) reading aloud; (4) reciting a piece of poetry while blindfolded; and (5) attending to the tick of a metronome. The movement in each case was undirected as to method of control, but directed as to amplitude, and as to rate, when the metronome was used.

In the third series of experiments, tests of the pressure of the middle and little fingers were made. In this series the vertical movements only were used. One half of the subjects were instructed to relax and the others to hold the fingers rigid, while the fourth finger moved.

In Series I, II, and III, the hand was supported on a table, so it was thought best to test the control of the fingers without any support for the hand save the carpal joint. Therefore, in the fourth series, the forearm was placed in an arm-rest so that it was supported just above the carpal joint, thus leaving the hand free. The subjects were then instructed to relax the fingers.

DESCRIPTION OF APPARATUS

The tridimensional apparatus for registering finger movement was not suitable for the purpose of our investigation, so we devised one apparatus for registering finger movements in the vertical plane and another for registering movements in the horizontal plane. Two drums, 30 centimeters in length, were placed three meters apart on a long table and joined by a smoked paper belt; this enabled us to use more than six meters of kymograph paper without change, and provided space enough to register the movements of the fingers of six reagents. The progress of each subject was easily followed from day to day, and the records of the movements relative to one another could be seen at a glance. The two drums were rotated by means of a small electric motor and their rate was controlled by the use of a rheostat and a Pillsbury speed reducer, to which a belt running around each drum was attached. The registering apparatus was as follows: (Fig. I) a small wooden box (X), 25 cm. x 12 cm. x 12 cm., was

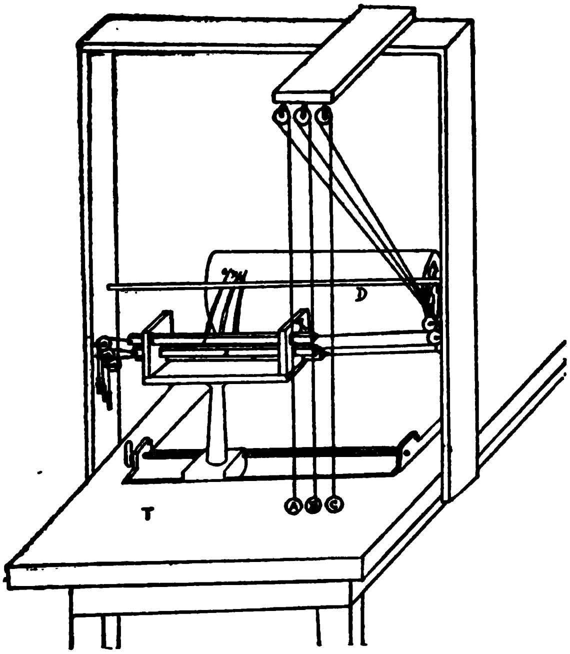

FIGURE 1

placed on the carriage of the kymograph. In each end of this box were three rectangular holes, 15 mm. x 6 mm., through which ran three bars (1, 2, 3), 40 cm. x 15 mm. x 6 mm., so adjusted that they could be easily moved back and forth in the horizontal plane; to these bars cords were attached and so directed by the use of pulleys that when the fingers were placed in thimbles (A, B, C) fastened to the other ends of the cords, any movement of the finger in the vertical plane pulled the bar in the horizontal plane. Weights attached by means of cords to the other ends of the bars pulled them back in place. Small holes, 3 mm. in diameter, were bored in the bars and in these were placed small pegs (a, b, c), tipped with fine wire, ground to a point, touching the smoked paper on the drum. These pegs registered the finger movements. Seconds were recorded by an electric time marker connected with a pendulum.

For recording movements in the horizontal plane, the following attachment was used in place of the box and bars described above: (Fig. II) a small box (X), 10 cm. x 10 cm. x 20 cm., attached to the carriage of the kymograph, served as a support upon which to fasten a wooden block (Y), 2 cm. x 8 cm. x 10 cm., on which markers were fastened by means of screws (1, 2, 3) which served as pivots on which the markers moved. The pivots were at a distance of 20 cm. from the small end of the rods and 10 cm. from the ends to which the upright rods were attached at right angles. The horizontal rods (a, b, c), which served as markers, were made of wood, 2 cm. x 2 cm. x 30 cm., and tapered toward the ends in which were placed small wires, 8 cm. long, curved slightly toward the ends, which were ground

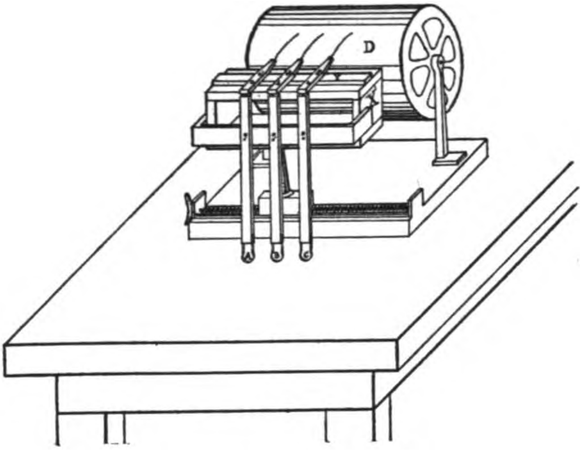

FIGURE II

to a point, so that they would mark readily on the drum. The upright rods worked on wooden pegs (4, 5, 6) as pivots running through the rods at a distance of 10 cm. from their upper ends and fastening them to the end of the box. These upright rods were made of wood, 2 cm. x 2 cm. x 40 cm., and to their lower ends thimbles (A, B, C) were attached and so adjusted as to fit the little, ring, and middle fingers when the hand lay flat on the table. The thimbles were 2 mm. above the surface of the table, so that the fingers did not touch the table during the lateral movement. This arrangement permitted the fingers and the markers to move in the same direction.

The apparatus used to record the pressure curve in Group I is shown in Figures IIIA, IIIB, and IV. T (Fig. IIIB) is a box,

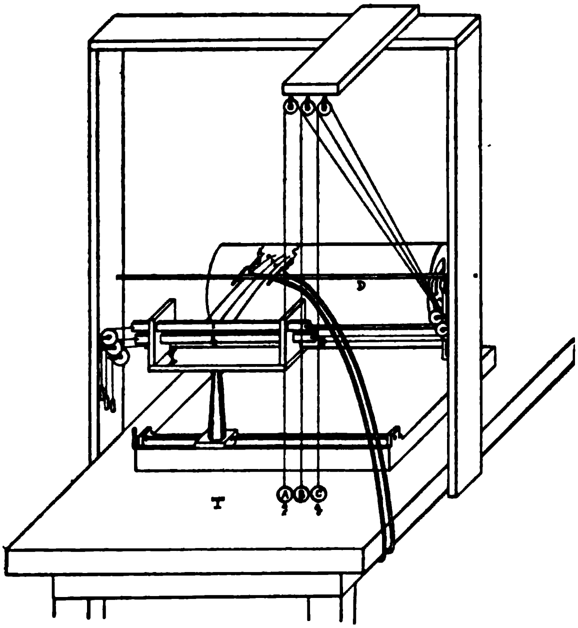

FIGURE III A

15 cm. x 30 cm. x 50 cm.; A and C are round pegs, 1 cm. in diameter, fastened in pistons of plaster of paris (B in Fig. IV), 5 cm. long and 2.5 cm. in diameter. The pistons worked in glass tubes, 10 cm. in length, and rested on coiled steel springs, 5 cm. long and 1.5 cm. in diameter. The glass tubes were fitted into

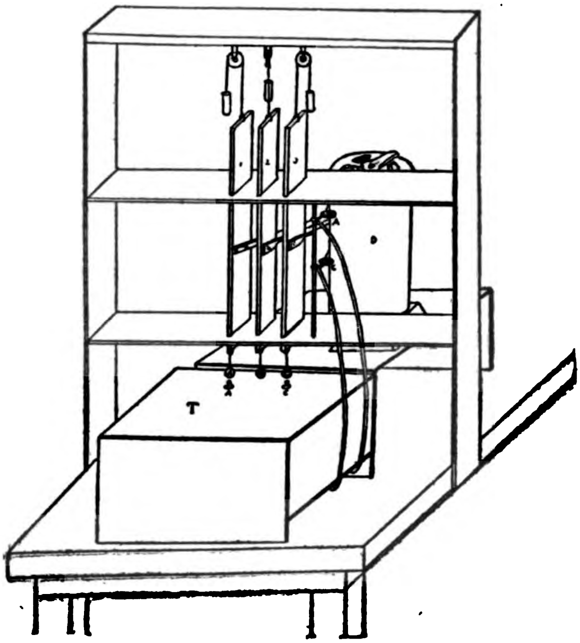

Figure III B

holes bored half way through the bottom of the box, and made air-tight by the use of sealing wax; through the center of the base of each large glass tube a small glass tube C (Fig. IV) 1 cm. in diameter, was inserted; the small tube extended up into the large tube through the center of the steel spring 3 cm., and distance of 3 cm. below the bottom of the box to receive the rubber tube running to the tambours A and C (Fig. IIIB). The small tubes were made air-tight by means of sealing-wax. The pegs A and C (Fig. IIIB) extended 2 mm. above the top of the box. The pistons were made air-tight by the use of oil. In this series, Group I, a vertical drum (D) and a recording apparatus (a, b, c), attached to vertical bars controlled by weights were used, as shown in Fig. IIIB. In Groups II and III a horizontal drum was used.

Statement of Method

The subject sat on a laboratory stool at the end of a table, placed his little, ring, and middle fingers in the thimbles with

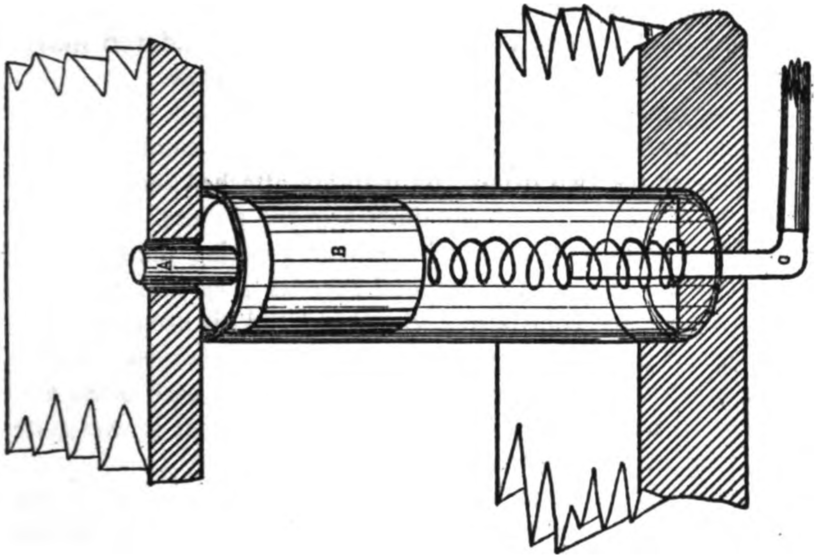

FIGURE IV

the palm of his hand laid flat on the table, and let his arm rest comfortably thereon. No directions were given in regard to the position of the other members of the body. The signal to move was given by means of a small electric bell. A few seconds before the signal to move, the signal "ready" was given.

The ring finger was selected first, because of the comparative ease with which apparatus could be adjusted to it, and because of its convenience for experimentation. In the second place, it usually has the least independent action of any of the fingers, hence would yield the best results for this experiment.

The subjects were tested daily for eighty seconds, and the tests were continued until the control process was practically perfect in each series. Conditions were kept as nearly constant as possible throughout the experiment. The test was given at the same hour each day. Any variation in the health or condition of the subject was noted.

We began the first series by requiring the reagent to move for one hundred seconds at each test; this was too long to secure the best results, as the fingers became so fatigued that control became impossible, so we reduced the time to eighty seconds. In the first series, we let each subject choose his own rate at first. We next tried various rates of 60, 70, 80, 90, and 100 movements per minute. The results are recorded below.

The objective side of the experiment consisted of a curve recorded, as already indicated, on the belt of smoked paper, passing over the two drums, by markers attached indirectly by means of cords, pulleys, and thimbles to the fingers. The time of the test and the position of the fingers during the same are accurately recorded. This method permits a careful study of the movement and control of each subject and his progress from imperfect to perfect control. The kymographic curves recorded by the six observers on the paper ran parallel to each other and each record was continued from day to day so that it was quite easy to follow the progress of the subjects.

Immediately after each test, the subjects were asked to describe what took place in their minds from the giving of the signal to start until the close of the test. As the experiment progressed, our questions were made more searching, and so the introspective reports are more definite. The nature of the initial cue, the control factor in the moving finger and the other fingers, the focal point of attention, were searched for, and usually they were clearly and definitely given by the subjects in their introspective reports. A study of these introspections enabled the writer to determine their respective mental types. The immediate mental antecedents operative in initiating the movement, we term the "cue". The mental concomitants of the movement, which seemed to guide the same, are termed "control processes".

PART I

SERIES I.—UNINSTRUCTED MOVEMENTS. NO DISTRACTIONS OR LIMITATIONS—SEVEN SUBJECTS

1. VERTICAL MOVEMENTS

a. *Preliminary statement*

It is not our purpose to make an historical study of the various theories, of volition, but rather an introspective study of voluntary motor control under experimental conditions, checked by objective data. We have laid special emphasis upon a study of the initiatory cue of the movements made and the control process of the movement after it has been initiated. These processes vary according to the mental imagery of the different subjects, and also according to the degree of control acquired by each. Several of the subjects reported that the could vary the initiatory cue at will, by concentrating the attention upon the visual image of the movement to be made or upon the kinaesthetic image, or even upon the signal. But as a rule the mental type of each reagent determined his initiatory cue and his control process also.

The records of this series were made with the eyes of the subjects open and without any restrictions whatever. The reagent, having taken the position described in the previous section, was directed at a given signal to move his ring finger, with the metacarpo-phalangeal joint as a pivot, as high as he could without moving the other fingers. He was told to control his other fingers—that is, he was to keep the ring finger moving and the other fingers on the table. The records of the finger movements of the subjects were small at first and revealed many movements of the middle and little fingers. Practice rapidly lessened the number of these accessory movements in each test and increased the extent of movement of the ring finger. The series was continued until the latter movement was practically automatic, or until the control was substantially perfect. Even after the control had become perfect, fatigue, headache, nervousness, or worry on the part of the subject were followed by irregular reactions.

The curves at the beginning of the first series show an irregular record, both in extent and in rate. The height of the curves is small and irregular in all of these early records except two; two subjects moved rapidly from the first, but their control of the other fingers was slight. They desired to make a large movement and so did not emphasize control, and the result shows that the little finger and the middle finger move in rhythm with the ring finger. The other four reagents made smaller movements with the ring finger, but show better control of the other fingers.

Three of the subjects had a tendency to raise the hand from the table at the metacarpo-phalangeal joint; this placed the hand in a strained position, but enabled the reagent to make a more extended movement of the ring finger and gave him better control of the other fingers as he was enabled in this way to place them under more muscular tension. Two of the subjects broke up this habit after several weeks' practice, but the other kept it for nearly four months.

Five of the subjects took a slightly leaning posture toward the hand that was active in the experiment. The whole organism was adjusted to this one activity. Sometimes the other hand would move as if it too were engaged in the work. Adjustment and tension of the muscles were observed quite frequently in the non-acting hand. This fact emphasizes once more the law of excess discharge, the tendency of the motor impulse to be drained off into channels other than those immediately essential and especially those of an anatomically symmetrical kind. During the first set of tests one reagent kept time by nodding her head as she moved her finger and counted one, two, etc., with each stroke of the finger. She gained perfect control after a few days' practice. The movement of the ring finger was not so extensive as that of the records of the other reagents, but her control of the other fingers was perfect after a few tests. Her speedy control was presumably due to the fact that she had had daily piano practice from childhood.

The first and second phalangeal joints of the fingers of three of the subjects were loose, and so the curves representing their records do not show the actual movements that took place, while using the metacarpo-phalangeal joint as a pivot. This difficulty was overcome after considerable practice. Finally the subjects were able completely to relax the muscles and tendons controlling the movements of the fingers, and then the control of the fingers to be kept quiet was perfect, and the movement became practically automatic.

Bair[1] says that learning to make a voluntary movement is largely a matter of learning to relax. Relaxation is first learned by withdrawing the attention from the movement just effected. A voluntary attempt to relax will merely increase tension. Our experiments show that the inhibition of the movement of a member of a group is first learned by keeping the member rigid by muscular tension and secondly by drawing the attention from it. The latter is the method by which complete relaxation is acquired. The kind of material in the focus of attention, which serves as initial cue and as control in the moving process is determined by the mental type of the reagent. We shall consider this more fully below, where we describe and analyze the introspections of the subjects that acted as reagents in our experiment.

In the following introspective accounts, tests of different chronological position in the series are presented in order that they may show a greater variety of conscious phenomena at the different stages of the problem. The experimenter rigorously avoided suggesting the special things reported. The terms used in the introspective accounts have their ordinary meaning. Kinaesthetic sensations are feelings of tension, movement, and the like, resident in the moving member and due to the latter's movement. Kinaesthetic images[2] are memory images in which kinaesthetic sensations prevail. Auditory image and visual image are used in a similar manner. Visual-kinaesthetic, auditory-kinaesthetic and auditory-visual, indicate the fact that both elements were present, the more vivid element being placed first.

---

[1] Psychological Review Vol. VIII, 1901, p. 470.

[2] Whether these are pseudo-images, in reality sensations, need not be discussed. They were reported by the reagents as images and may so stand here.

b. RIGHT HAND

(1) *Introspective Reports*

Subject P.

First Trial.—The initial cue was a visual-kinaesthetic image and visual and kinaesthetic perceptions were the control processes. Attention on extent of movement of ring finger. Attention oscillated. Saw little finger raised, attention was attracted to it, and then followed an irregular movement of ring finger. The latter became fatigued toward the close of the experiment, and the extent of movement became less, and the rate irregular. Motor control was lost after fatigue became great. Thought of record that he was making on the drum.

Fiftieth trial.—The initial cue was a visual image of the anticipated movement. Watched the members of the group. Attention was centered on control of all the fingers rather than on extent of movement. Paid, however, little attention to anything. Movement was practically automatic. Heard a locomotive whistle.

Subject B.

Fourth trial.—Visual image of movement was the initial cue. Visual-kinaesthetic perception was the control process. Tried to concentrate attention on the ring finger and its movement. Little finger was drawn up by the weight which pulled the recorder back into position. Attention oscillated to the little finger. Middle finger moved next and drew attention to it. Was conscious of making a poor record which seemed to distract attention and cause embarrassment. Conscious of fatigue in little finger.

Sixtieth trial.—Had a vivid visual image of the movement before the finger began to move. Attention on regular movement of ring finger and control of the other fingers. Visual perception of the moving finger controlled its movement both as to extent and regularity. Conscious of good control.

Subject S.

Second trial.—Visual idea of the movement was the initial cue. Movement was controlled by visual perception of the ring finger. Attention on extent of movement of ring finger. Raised little finger once. This attracted attention to it in order to put it in position. No fatigue, but conscious of strain in arm.

Sixtieth trial.—Visual-kinaesthetic ideational cue. Attention on extent and regularity of movement which was guided by muscular feeling in the ring figner. Some muscular strain in hand. Little finger moved slightly; watched it to keep it down.

Subject G.

Eighth trial.—Kinaesthetic image of the movement was the initial cue. Attention on movement and on trying to keep the other fingers still. They both moved and attention was attracted to them. When attention was focused on putting little finger down on the table, the ring finger did not make its usual record. Was conscious of this at the time but unable to prevent it. Felt pain in the region of the scapula. Conscious of effort in the ring finger.

Fiftieth trial.—Kinaesthetic image was the initial cue. Arm ached at the beginning in making the adjustment. Attention was centered on keeping other fingers down and on trying to make a good record. Felt that she was making a good record and wondered why. Tried to relax arm. Kinaesthetic perception of the moving finger.

Subject M.

First trial.—Kinaesthetic image of ring finger preceded the movement which was controlled by resident sensations. Tried to move ring finger. No thought of other fingers. Felt that ring finger would not move rightly.

Fiftieth trial.—Visual-kinaesthetic imaginal cue. Visual-kinaesthetic perception of ring finger controlled the movement. Attention on moving more slowly than usual and also on extent. Just let the finger "go itself". Had no difficulty in keeping the other fingers from moving. Did not keep attention on the finger all the time toward the close of the test. Movement was practically automatic.

Subject K.

First trial.—Visual image preceded the movement which was controlled by visual perception of ring finger. Attention was focused on the movement of ring finger, but it oscillated to middle finger and to little finger. Felt fatigue in forearm.

Thirtieth trial.—Visual image initiated the movement. Attention on extent of movement and on the perfect control of the other fingers. Had a visual image of the record as it would appear on the drum. Conscious of perfect control.

(2) *Summary of Individual Introspections*

The introspections reported by the reagents show that attention was generally focused upon the idea of the extent of movement of the ring finger. The subjects as a rule emphasized extent of movement too much, and consequently they were unable completely to inhibit the movements of the middle and little fingers.

M. reported that he could control his movement better when he moved the finger rapidly—at the rate of sixty or seventy times per minute. He reported also that this gave him better control of the other fingers. This report is confirmed by a study of the curve recorded on the kymograph.

P., on the other hand, moved deliberately and soon gained complete control of his fingers. In the first four or five tests, he reported that he had difficulty in getting definite resident sensations in the moving finger, and the record shows a corresponding irregularity in the movements of the ring finger and inability to inhibit the movements of the other fingers. After a few tests he focused his attention with regularity on extent of movement, and was able to disregard the other fingers. He said that he had no thought of them. When *attention* was focused *completely* upon the movement of the ring finger, its record was even and regular and the *inhibition* of the other fingers was *complete*.

G. was ambitious from the start to make a large movement. Her attention was focused on extent of movement rather than on voluntary control. It took many trials to eliminate the movements of her other fingers. This was due in part to the size of the thimble which was too large for her ring finger and so slipped at times, thus causing the other fingers to move.

During the first set of this series G. reported that while her attention was focused on extent of movement, the latter was controlled by a visual perception of it. Whenever her other fingers were drawn up by force of the weights or moved in the effort to move the ring finger, if attention was attracted to the little finger or the middle finger, it was *after* the movement had taken place. Sometimes, one of the other fingers would be pulled up gradually by the weights without any knowledge on the part of the subject of the position of the finger; but in the effort to move the ring finger or in the effort to make sure that the other finger was down, the latter moved and then attention was directed to it. Quite frequently the record shows that the other fingers moved without the knowledge of the subject.

G. reported muscular fatigue and strain in the muscles of the forearm just below the elbow and in the muscles of the arm in the region of the scapula, whenever the test was continued longer than eighty seconds. She reported also sensations of strain in tendons of fingers and hand. When her attention was strongly focused on the movement of the finger of the right hand, she reported a twitching of the muscles in the left forearm. Extent of movement was judged by the tendinous strain in the moving finger.

S. was able to make a large movement from the first; this was largely due, as we have said above, to the shape of his hand and fingers. When the palm of his hand was placed flat on the table, the tips of his fingers, when in their normal position, were not touching the table. This fact made it more difficult for him to control his other fingers, when he was moving his ring finger, because his joints are loose and permit the fingers to bend back readily at the phalangeal joints. It took him a long time to overcome this.

His control process was a visual image of the curve that he was making on the drum by the movement of the ring finger. A visual image of the record guided his movements both as to extent and regularity. Only once during Series I, which was continued for two months and a half, did this subject report kinaesthetic perception—the feeling of the moving finger—as the process which guided his movement. His movement finally became semi-automatic and his control perfect for several days at a time and then a day would come in which he could not inhibit the movements of the other fingers. This could usually be accounted for by overwork—mental or physical. He always reported attention attracted to the other fingers *after* their movement. He frequently reported strain in the tendons of the back of the hand and in the moving fingers. Toward the close of this series his movement was so nearly automatic that he gave little attention to the fingers, and so reported only very vague visual images of his movement.

K. was very definite and accurate in his introspective reports. His control was poor at first, but his determination to succeed, and his ability to concentrate his attention on his problem hastened the learning process, so that he gained perfect control of his fingers in the course of two or three weeks. In the early part of Series I, he reported a conscious struggle with his thumb which had a strong tendency to move, but it was controlled with great effort. He was the only one that reported any tendency to move either the thumb or the forefinger.

His starting cue was strongly visual from the first. His control process was also strongly visual, and usually consisted of the visual image of the movement of the finger. Quite frequently he reported that his movement was controlled and regulated by a visual image of his record on the drum. These facts are more clearly and definitely brought out in the blindfold series. K. *learned* to control his fingers more quickly than the other subjects, owing to his concentration and his determination to succeed. At first he was not able to control extent of movement of the ring finger, and was not able to inhibit the movement of the other fingers. Although he learned more rapidly than the other subjects, he did not gain perfect control so quickly as Sn. because she had good control from the very first in Series I and II.

B (the writer) was much older than the other subjects, and was not able to make so extended movements as they, nor was his record so uniform from day to day. In Series I, his starting cue was uniformly visual, and his control was the visual perception of the moving finger aided by the kinaesthetic perception of the movement. From the first he was not able to inhibit the movement of the other fingers. Attention oscillated between the ring finger, and the middle finger or the little finger. But attention was always attracted to these fingers *after* their movement. This rule was uniform with all the subjects. Fatigue, worry, or headache regularly lessened the ability of the subject to control his fingers. Confidence that he could perform the experiment with perfect control was a great help toward success.

The subjects uniformly report that attention goes to the middle and little fingers *after* their movement. So long as these fingers are completely relaxed the subject reports that he is not conscious of them; but the instant they move, consciousness appears and attention is focused upon them in order to control them.

c. LEFT HAND

(1) *Preliminary Statement*

The left hand movement was a repetition of the right hand movement. It may be remarked that all the subjects were right handed. The purpose of this part of the experiment was to verify the results of the first part and to determine the effect of training the fingers of the right hand upon the process of learning a similar movement by the members of the left hand. Only five tests were given in this series. We give an introspective report of each individual below:

(2) *Introspective Reports*

Subject G.

Fourth trial.—Kinaesthetic image of the movement was the initial cue. The ring finger was controlled by kinaesthetic perception of it, and by visual image of it. Did not look at the hand at all. Sensation of touch as the finger came down on the table was an important factor of the control process. The other members of the group were controlled by tendinous, muscular, and tactile sensations. The tendinous strain was prominent. The kinaesthetic sensation was felt in the whole finger. Attention was focused on the movement of the ring finger and especially on the amplitude of the movement. No fatigue.

Subject Sn.

Fourth trial.—Auditory-kinaesthetic cue. There were three control processes: tactile sensation as the finger came down to the table, kinaesthetic perception, and visual perception of the moving member. The sensation of touch seemed to be very important as an element of the control process. Tactile sensation controlled the other members of the group as they lay on the table. Subject found that she was able to control her finger without looking at it; then a visual image of it appeared. Attention was focused on the movement of the ring finger.

Subject S.

Fourth trial.—Kinaesthetic cue. Kinaesthetic perception of the ring finger was the chief element of control, but visual perception of it seemed to aid in the control of the movement. Was conscious of great strain in the phalanges of the ring finger in the metacarpo-phalangeal joint and in the volar side of the wrist. The other members of the group were kept down by means of muscular tension. Attention was centered on watching the movement of the ring finger and on the sensations in the finger. Other fingers were in the field of attention. Was conscious of good control.

Subject M.

Fifth trial.—Idea of the feeling of the movement to be made was the starting cue. The movement was controlled by the kinaesthetic perception of the ring finger. Did not watch it but looked out of the window. Other members of the group were controlled by tactile sensation of table. Had no other sensation from them. Attention was not focused on anything.

Subject P.

Fifth trial.—As soon as the signal bell rang, P. had an articular image [?] of the finger. Sensation was localized in the metacarpo-phalangeal joint. Then the movement followed. Kinaesthetic perception of the ring finger was the principal element of control—sensation continued in the joint. Tactile sensation of finger coming down on the table, was an element of control also. Other fingers were relaxed. They were controlled in part by visual perception. Attention oscillated—no attention to movement during a part of the test.

Subject B.

Fifth trial.—Kinaesthetic-visual-auditory cue. Both visual and kinaesthetic perception of the ring finger controlled its movements. Articular sensations in metacarpo-phalangeal joint. Other members of the group were controlled by visual perception and by sensations of tendinous strain in the first phalanges. Attention was focused on the amplitude of the movement.

(d) Summary of Left Hand Movement in Vertical Plane

During the right hand practice there was constant innervation of the fingers of the left hand so that when the left hand movement was begun, only five trials were given in this series because the control was practically perfect from the first in regularity and amplitude of the movement of the ring finger and also in the complete inhibition of the movement of the other members of the group. The long practice with the fingers of the right hand seemed to be the explanation for the above results. It required more than two months—sixty or seventy trials—for the subjects to gain complete control of the movement of the finger of the right hand in the vertical plane. When the fingers of the left hand were placed in the thimbles, and the signal given, the ring finger moved almost as easily and with as great amplitude as though it were continuing the practice of the finger of the right hand. We consider this subject more fully in the general summary of the results of the experiment.

The presence of the kinaesthetic image as the initiatory cue was more common than in the previous right hand movement. The auditory cue was usually reported by subjects whose movements were practically automatic. Either auditory or kinaesthetic cues could be used successfully by some of the subjects, but the kinaesthetic image was the one generally used. M. frequently reported a visual cue; occasionally he reported a 'general idea of movement' as the immediate precursor of the finger's activity.

The movement was regulated and controlled chiefly by kinaesthetic perception of the moving member. The tendinous, articular, and muscular sensations were more carefully localized by the subjects than in the previous series. The tendinous sensations were usually localized in the first phalanges and in the fourth metacarpal but more commonly in the former and frequently in both during the experiment. Visual perception of the moving member and of the whole group was present as an element of control, but was not usually so important a factor as the kinaesthetic perception. Sn. reported that she could move the finger better without looking at it. This fact would seem to indicate that for her the visual element was not an important factor in the control process. Tactile sensation was also an element of control. As the finger came down upon the table, both the thimble and the ring finger touching the table gave rise to a vivid perception of the position of the finger.

2. Lateral Movements

a. *Preliminary Statement*

The lateral movement of the ring finger presented more difficulties than the vertical. The ligaments binding it to the little finger and the middle finger are so arranged that any extensive movement of the ring finger in the lateral direction would always pull one or the other of the two adjacent fingers; so that the movement of the latter did not always mean that the muscles controlling them had contracted.

In the second place, movement of the ring finger in the lateral direction is not so common as movement in the vertical plane. But the second difficulty was not so formidable as the first; for, with the exception of the writer, this movement was learned rapidly with almost perfect control of the other fingers. The first records were very discouraging—all the fingers moved and even the thumb was held in a strained position and moved slightly. The records show how rapidly persistent, faithful, regular practice will overcome these difficulties.

The following introspective reports of the subjects are fair samples of the psychical phase of the lateral movement of the fingers of the right hand. In general they resemble the previous reports.

b. Right Hand

1. *Introspective Reports*

Subject G.

First trial.—Movement of ring finger was initiated by a kinaesthetic idea of the movement to be made. The movement was controlled chiefly by kinaesthetic perception of the moving finger, supplemented by a visual perception of the record as it was being made on the drum. First phalangeal joint ached. Muscular tension controlled the other fingers. Attention was focused primarily on the movement of the ring finger, and secondarily on idea of moving in such a way as not to disturb the other fingers—steadily and not extensively.

Tenth trial.—Kinaesthetic cue. Pulled down with the other fingers to try to fix them firmly, and then withdrew attention from them. Was conscious of good success. Kinaesthetic perception controlled the ring finger; visual perception of the record used out of curiosity only, but not for control. Looked down at other fingers once and felt that control was being lost, and went back to watching the record. No strain and no fatigue.

Subject Sn.

First trial.—Auditory cue—the signal initiated the movement. Visual perception of the fingers supplemented by kinaesthetic perception were the control processes. Attention was focused on the ring finger, but the other fingers took a part of the attention.

No fatigue. Kinaesthetic sensation in the metacarpo-phalangeal joint.

Ninth trial.—Auditory cue. Visual perception of the group was the chief process of control. Had kinaesthetic perception of the ring finger, and also of the little finger when it moved. Attention was focused on the ring finger, with the other members of the group in the field. Get on better when attention is focused absolutely on the moving finger. No fatigue.

Subject M.

First trial.—Starting cue was a visual image of the movement to be made, which was controlled by both visual and kinaesthetic perception. Attention was focused on the ring finger, but oscillated to the other fingers. Conscious of strain in all the fingers.

Tenth trial.—Auditory cue. Movement of ring finger was controlled by visual perception of record. Conscious of good control of ring finger. Visual perception of the little finger showed that it was moving, but had no kinaesthetic perception of it. Attention on record and on the cause of the movement of the little finger.

Subject P.

First trial.—Auditory cue. Visual perception of movement. Peculiar strain in the metacarpo-phalangeal joint. Attention was focused on the ring finger but was attracted to the little finger when it moved.

Eleventh trial.—Auditory-kinaesthetic cue. Kinaesthetic perception of movement was localized in the metacarpo-phalangeal joint of ring finger. Other fingers were completely relaxed. No kinaesthetic perception of them or sensation in them. Had a visual perception of them. Attention was focused on the movement of the ring finger.

Subject B.

First trial.—Auditory-kinaesthetic cue. Attention oscillated from ring finger to other fingers. Attention was really on the group. Was conscious of poor control. Visual perception of record and of moving finger were the control processes. The kinaesthetic perception was vague.

Eleventh trial.—Auditory-visual-kinaesthetic cue. Watched the record as it was being made on the drum very closely; fingers were controlled in this way. Had a visual perception of the fingers occasionally. Attention was focused on the ring finger most of the time, but the other fingers were in the field. Kinaesthetic perception of the group helped to control the process.

Subject S.

First trial.—Auditory cue. Conscious of poor control. Attention was on little and middle fingers chiefly in order to keep them from moving. It took little attention to keep ring finger moving. Attention to other fingers made control of them easier.

Eleventh trial.—Visual cue. Watched the record as it was being made on the drum; also had a vague kinaesthetic perception of the movement. Was conscious of good control. Attention was focused on record most of the time, but it oscillated. Conscious of irregular movement of ring finger due to strain and fatigue. Not conscious of middle or little finger.

2. *Summary of Right Hand Lateral Movement*

Movement in the lateral direction was learned much more rapidly than movement in the vertical plane. This result is probably due to the practice and training acquired in the previous movement. No unqualified assertion can be made, however, for transfer of training was not the problem immediately in hand and no adequate control tests were employed to justify sweeping affirmations regarding this point.

P.'s initial cue was uniformly kinaesthetic throughout the tests on lateral movement. Adjustments were always made in advance of the movement, and the signal seemed simply to set off the movement for most of the subjects; but P. always reported a kinaesthetic idea of the movement to be made as preceding the actual movement.

Sn.'s initial cue was usually auditory-kinaesthetic, but occasionally she reported a visual image of the movement to be made as her starting cue and once the visual perception of the moving drum. Her fingers were adjusted and she was waiting with strained attention for the signal and as the drum started to move before the signal was given, the visual perception of the rotating drum set the finger to moving almost automatically.

The initial cue of G. was rather evenly divided between visual-kinaesthetic and auditory-kinaesthetic, the auditory predominating. But M. on the other hand reported a visual cue only three or four times during the whole series. His cue was usually auditory. B.'s cue was usually auditory-kinaesthetic, but he frequently reported auditory-visual-kinaesthetic as his starting cue. P.'s initial cue was invariably auditory-kinaesthetic.

The *control* processes of the subjects were made more varied than in the preceding series. During one experiment one mental process would be the chief element of control, and during the next experiment another sort would predominate. At other times two or three mental factors would enter almost equally. Visual perception of the record and kinaesthetic perception of the moving finger were the most common controls.

G. reported visual perception of the record as it was being made on the drum by the recorder and kinaesthetic perception of the moving finger as the usual control processes. She emphasized the importance of the kinaesthetic factor which was localized in or near the metacarpo-phalangeal joint. She found, however, when she directed visual perceptual attention from the record to the fingers, that control was lessened and that it was necessary to watch the record intently in order to make the control perfect. It would seem that the visual perception of the record was a very important element of control, both of the moving finger and of the other members of the group.

Sn.'s movement was controlled by visual perception of the moving finger and by kinaesthetic perception of the movement also. She always watched intently the moving finger. This was her chief source of control; the kinaesthetic element was only supplementary to the visual. The extent of movement was controlled by the kinaesthetic perception which was usually reported as vague.

M. tried to control his movement in the lateral direction during the first set of experiments in this series by visual perception of the ring finger which was supplemented by kinaesthetic perception of the movement. But this method was not successful. In the next place he tried watching the record intently as it was being made on the drum. This method gave better control and was used until the process was practically automatic. The kinaesthetic element was recognized and used as an element of control throughout the entire series.

P. tried various means of control: at first he watched the moving finger but failed to gain control; in the second place he tried watching the record, which gave better results; in the third place, he alternated between visual perception of the record and visual perception of the fingers. Kinaesthetic perception of the moving finger was recognized as an important element of control. Once he recognized it as the only element. The kinaesthetic sensation which gave rise to the kinaesthetic perception was always localized in the metacarpo-phalangeal joint of the ring finger.

B. tried various methods of control. Watched the fingers at first, but that method was not successful. Visual perception of the record assisted by kinaesthetic perception of the moving finger seemed to give the best results. He was not able to make a perfect record during the entire series.

Visual and kinaesthetic perception of the members of the group were the elements of control used by S. during the first part of the lateral movement. This method did not seem to give good results, but the visual perception was supplemented by kinaesthetic perception of the moving finger. His visual perception of the record became very vivid while the kinaesthetic perception was vague toward the close of this series.

The process of inhibiting movement in the fingers to be kept quiet depended upon muscular and tendinous sensations during the first stage of the control. Three of the subjects, however, used visual perception of the fingers and also visual perception of the record as elements of control. In the lateral series they relied entirely on muscular strain to control the quiescent members of the group during the first trials. All the subjects reported the tendinous and muscular strain in these fingers during the first several trials. One of the subjects emphasized visual perception of the fingers as the chief element of control; three, visual perception of the record.

c. GENERAL SUMMARY OF SERIES I

There are three rather definitely defined stages of the inhibitory process. The first is the stage of muscular and tendinous tension in which the subject tries to inhibit the little and middle fingers by keeping the muscles tense. In the second stage, the muscles are partially relaxed, and the muscular sensation is vague, and the record becomes approximately perfect. In the third stage, the muscles become completely relaxed, the subject is not conscious of the non-moving members of the group or at most only vaguely conscious of them, and the record is usually perfect.

Quite frequently, however, the middle finger or the little finger moves, and yet the movement does not give rise to any kinaesthetic sensation and so the subject does not know that any movement has taken place until he examines the record. On the other hand, the subject frequently reports kinaesthetic perception of the movements of the other members of the group when the records show that no movement has taken place. These cases seem to be illusions of movement due to muscular tension which gives rise to vivid kinaesthetic images of the supposed movement. Complete relaxation of the inhibited members seems to be the goal of perfect control; and this is attained by withdrawing the attention from the non-moving members and by focusing it on the moving finger.

The field of attention usually includes all the members of the group. The movement begins with the focus of attention on the movement of the ring finger; but the muscular and tendinous strain in each finger seems to cause the attention to oscillate from one member of the group to another. The introspective reports of all the subjects show that voluntary attention always preceded the adjustment and movement of the ring finger; but they show also that the involuntary and non-voluntary movement of the other members of the group were followed by attention to them. Their movements did not ordinarily follow upon attention to them, but when the focus of attention went to them it was usually after their movement had begun. The process of attention was always most active at the point where new adjustments were needed to control the situation.

The conscious elements in the focus of attention varied in the first part of each series. Each of the subjects began the movement in the lateral direction by trying to fixate upon the visual perception of the moving finger; but the introspective reports show that the kinaesthetic perception of the moving finger was more vivid than the visual perception during the first part of the series. At this stage of the experiment the attention oscillated. But as the control became more perfect, attention became focused on the kinaesthetic perception of the moving finger, the visual perception of the record, or the visual perception of the moving finger. G. used the first form of control, M. the second form, and Sn. the third form; P. used both the first and second forms with preference for the first; B. used the same forms as P. but with preference for the second form. S. focused his attention on the record with very vague kinaesthetic perception of the movement.

SERIES II. DISTRACTIONS AND LIMITATIONS—SEVEN SUBJECTS

1. THE BLINDFOLD

The experiments of Series II followed immediately those described in Series I, with the same reagents.

a *Purpose*

The purpose of the blindfolded series was the elimination of the sensory element of visual control in order to enable the subject better to estimate the value of visual perception in the control processes, and especially its significance in comparison with the ideational visual element. One of our subjects immediately substituted the visual image of the movement for the visual perception and so his control was not affected. As a rule, however, the cutting off of the sensory visual element affects both movement and control processes until the subject can readjust himself to the new condition. This is true despite the fact that kinaesthetic, tactual, and auditory sensory material and visual ideational material are still available.

The cutting off of the visual perception affected the regularity and the extent of the movement of five of the subjects. The muscular sense was soon successfully used to gain control over the *extent* of the movement and its regularity. But the regularity of the *rate* of movement was controlled invariably by the auditory factor—the tick of the time marker, the tap of the thimble, or an imagined rhythm.

A metronome was introduced into the experiment primarily for the purpose of distraction, but from the first it was a positive help to most of the subjects; it made their records regular and uniform in height. When the records had become thus regular and substantially free from error, the metronome was set at a faster rate—eighty strokes per minute, and then changed to sixty and back again to eighty during one trial. Two metronomes were used, each set at the regular rate, so that the change from the faster to the slower rate could be made without losing a beat. The change of rate distracted the attention of the subjects for a short time, but each rapidly gained control again and moved with the rhythm of the metronome. The change from the faster to the slower movement caused more difficulty than the change from the slower to the faster rate.

Counting was used as a distraction; the subjects were required to isolate the counting from the movement.

The subjects were also at times instructed to recite a familiar poem while moving the finger in time with the metronome but were required to isolate the rhythm of the poem from that of the movement and the metronome. As a further distraction, the beat of the metronome was changed during the test from 84 to 48 and back again from 48 to 84.

The subjects were further required to read easy prose, and at the same time move with the tick of the metronome, and to isolate the rhythm of articulation from that of the movement.

b. *Introspective Reports*

Subject G.

The movement was initiated by an auditory-kinaesthetic cue. Kinaesthetic perception of the ring finger was the principal control factor, but a vivid visual image was present during the whole trial. Other fingers were controlled by pressing them down on the table. Attention was focused on the perception of the moving finger—the visual image being emphasized as an element of consciousness but not regarded as a factor of the control process. Was conscious once, through tactile sensation, of the movement of the middle finger.

Subject Sn.

Auditory-kinaesthetic cue—auditory element being stronger than the kinaesthetic. Had a visual image of the whole group. Sensations in the ring finger, and sensation of touch when the finger came down on the table controlled the movement. Other fingers were relaxed and hardly thought of. Attention was focused on the movement of the ring finger.

Subject M.

Auditory-kinaesthetic cue. Kinaesthetic perception of the ring finger was the control process. No visual images of any kind. Other fingers were relaxed but they moved slightly, though their movement did not give rise to kinaesthetic sensations. Attention was focused on the feeling of the movement. The blindfold seemed to have very little effect. Kinaesthetic sensations came from every part of the middle finger. Tactile sensations were localized in the tip of the little finger.

Subject P.

Kinaesthetic cue. General idea of movement controlled the process, with very vague consciousness of what was going on. Had no visual image at all. Did not think of the other members of the group. Attention was not focused on anything. Movement was automatic.

Subject B.

Auditory-kinaesthetic-visual cue. Kinaesthetic perception of the ring finger and visual image of it were the control processes. Other fingers were controlled by tactile sensations and by sensations of tendinous and muscular strain. The visual image of the movement was vague and exaggerated both in its amplitude and accuracy. Attention oscillated. Was conscious of perfect control. The visual image took the place of the visual perception. Kinaesthetic perception was the chief control process. Articular sensations were localized in the metacarpo-phalangeal joint.

Subject S.

Auditory-kinaesthetic cue, the latter being much stronger. Had hand adjusted waiting for the signal. Kinaesthetic perception of the ring finger and visual image of it were the control factors. Could not decide which was the stronger. Movement was more irregular than usual, but the other fingers did not move. Slight strain in the ring finger. Other fingers were held down by tendinous and muscular tension and by sensations of touch as they lay on the table.

c. *Summary of Results of Blindfold*

Visual perception as a control factor was of course completely eliminated by the use of the blindfold; those subjects that relied on visual control were stimulated to try and substitute the visual image for visual perception. One subject was able to make this substitution at once—using the visual image both as a starting cue and the principal element of control. The blindfold caused great disturbance in the inhibitory control for the other subjects thus indicating the essential röle of visual perception in their motor coördinations. After a subject had gained sufficient control of the group to withdraw his attention from the members whose movements he wished to inhibit, any non-voluntary movement of the latter attracted attention to them again.

2. BLINDFOLD, METRONOME AND COUNTING

a. *Introspective Reports*

Subject G.

Kinaesthetic image of the movement was the starting cue. Vivid kinaesthetic perception of the ring finger, but vivid visual images of both the ring finger and the metronome were present throughout the test. Other fingers were kept down on the table by pressure. Had a visual image of them. Attention was primarily on keeping with the rhythm of the metronome, and secondarily on the amplitude of the movement. Had articular sensation in the metacarpo-phalangeal joint, and tendinous sensation in the first phalanx of the ring finger.

Subject Sn.

Auditory-kinaesthetic cue. Had a kinaesthetic image of the upward movement before it began. Movement was controlled at first by visual image of the ring finger, and then the idea of the rhythm of the metronome and of keeping time with it were the principal factors of control. The visual image still continued, and also vague kinaesthetic perception. The other members of the group were relaxed and so little attention was paid to them. Attention was centered on the movement and on the metronome.

BLINDFOLD AND COUNTING SERIES

Subject G.

Kinaesthetic cue. Had a vivid visual image of ring finger throughout the whole trial, and also vague visual image of the group. Heard the rhythm of the movement all the time—the thimbles hitting the table. Had a tendency to make the counting twice as fast as the movement, and had to keep pausing to keep from doing this. Movement was controlled by kinaesthetic perception of the ring finger. It was easier to count regularly than to keep the movement regular. Other members of the group were not in consciousness. Attention was centered on the amplitude and regularity of movement. Muscular strain in forearm. Counted to 111.

Subject Sn.

Auditory cue. Counted and moved together. Controlled the movement by counting and by kinaesthetic perception—articular sensation in the metacarpo-phalangeal joint of the ring finger. Attention was on the regularity of the movement—both the amplitude of the curve and the distance between the waves as shown on the record. Paid little attention to the other fingers—knew they were on the table by sense of touch. Sn. counted just as she moved—could not count otherwise. Could not separate movement and counting. Once when she lost breath in counting, she held the finger back until counting began. Counted to 121.

b. *Summary of Results of Blindfold, Metronome and Counting*

Neither the metronome sounds nor the counting affected the initial cue of the subjects. The method of control was essentially the same as before. The counting greatly distracted one subject, so that he was not able to inhibit the movement of the other members of the group. Another could not separate the counting and the movement; the two rhythms ran together. A third tended to do the same, but with great effort he was able to separate them. Four of the subjects counted faster than they moved. The counting caused oscillation of attention between the counting and the moving. Attention seemed always to go to the less automatic process—to the point where new adjustments were needed.

3. SERIES BLINDFOLDED, RECITING POETRY, WITH METRONOME

(*Rate changed from 84 to 48 and back again from 48 to 84*)

a. *Introspective Reports*

Subject G.

Cannot remember starting at all. No visual image of movement. Vague kinaesthetic perception of moving finger. Attention oscillated from trying to repeat the poem and trying to listen to metronome. Embarrassed by not keeping the rhythms together. Tended to keep the rhythm of metronome and poem together rather than finger and metronome.

Subject Sn.

Auditory cue. Attention was focused on repeating poem. Controlled moving finger by rhythm of metronome. Great tendency to recite rapidly when the metronome was moving fast and slowly when the metronome was moving slowly. Difficulty in keeping from reciting rhythmically. Conscious of good control. Little attention to fingers. Much amused.

Subject M.

Auditory cue. Kinaesthetic control of ring finger. Attention on rhythm of metronome. Conscious of movement of little finger.

Subject P.

Auditory cue, but it was not distinct. Kinaesthetic control of ring finger. Attention was focused on reciting the poem. Not conscious of other fingers.

Subject B.

Auditory cue. Attention oscillated between the reciting of the poem and the tick of the metronome, and the ring finger. Conscious of imperfect control. Vague kinaesthetic perception of moving finger. No visual image.

Subject S.

Auditory cue. Attention on keeping rhythm of movement with rhythm of metronome. Conscious of the movement of little finger by sensation of touch and by kinaesthetic perception.

b. *Summary of Introspective Reports*

In the tests preceding these in which a familiar poem was repeated during the movement, the subjects were directed to move with the rhythm of the metronome. In the poem test, the subjects still kept time with the metronome, but tried to isolate the vocal control from the control of the finger. This necessarily caused oscillation of attention, and in listening to the metronome the subject would drift into the rhythm of the metronome in reciting the poem. This oscillation caused some embarrassment at first and imperfect control, but after a few trials the control became perfect and automatic. The reports show that the subjects depended chiefly upon auditory control processes.

4. READING PROSE

a. *Introspective Reports*

Subject G.

Kinaesthetic cue, but started before the signal was given. Became interested in the reading and paid little attention to the movement, which was controlled by kinaesthetic perception. Had an occasional visual image of the ring finger. Wondered if she should not be asked how much she remembered of what she read.

Wondered if she was reading intelligibly, and if record was regular. Reading did not affect movement.

Subject P.

Attention was concentrated on the reading and it was difficult to determine what the starting cue was—but started with the signal bell. Attention oscillated between the fingers and the reading, but for the most part it was on the latter—both the words and thought. Got the thought. Movement of the ring finger, which was almost automatic, was controlled by vague kinaesthetic perception of it. Articular sensation in the metacarpo-phalangeal joint. Other fingers were rigid at first, and then they were hardly in consciousness.

b. *Summary of Results of Reading Prose*

The reading of easy prose sometimes caused the attention to oscillate between the reading and the movement of the finger or between the reading and the sound of the metronome. There was a tendency to read faster when the metronome changed from slow to fast and *vice versa.* There was not so much tendency to read rhythmically as there was when the poem was recited, but it required more practice to acquire automatism than in the previous series, and there was a greater oscillation of attention of four of the subjects; while the attention of the other two (ladies) oscillated, it was more strongly concentrated on the reading. The visual-articulatory distraction of reading the easy prose caused more disturbance of the control than the recall-articulatory distraction of reciting the familiar poem.

SERIES III. PRESSURE CURVE

a. *Object of Pressure Test*

The reports from several of the subjects in the tests described above raised the question as to the importance of pressure as an element of the process of inhibition, as they frequently reported that the middle and little fingers were controlled by means of pressure on the tips of the fingers. In order to obtain an objective record of the pressure of these fingers, to compare the relative value of the methods of relaxation and contraction, to show the relative amount of pressure used in inhibition during the learning process, the effect of rate on pressure, and the relation of rate to fatigue, three new groups of six subjects each were selected. All were right handed.

1. Group I

O., Sc., and G. had had no preliminary training in finger movements. M. had taken a few piano lessons when a little girl but had practiced none since. Motor control was naturally easy for her. S. used a typewriter occasionally but had never taken lessons. V. had never taken piano lessons but amused himself occasionally by playing.

Three of the subjects, V., Sc., and S., were instructed to relax their fingers, and the other three, O., G., and M., to keep their fingers rigid, the antagonistic muscles being kept tense. The subjects were instructed to move the tip of the ring finger, using the metacarpo-phalangeal joint as a pivot, through the space of two centimeters at the rate of two times per second for one hundred seconds. After resting for three minutes, a second test was given. The amplitude was somewhat irregular because the subjects were not able to judge accurately the distance.

b. *Variation of Pressure*

During the first stages of the learning process the amount of pressure varied greatly during each test; the pressure curve showed sudden, sharp, and irregular changes. But after the subjects learned to inhibit the movements of the little and middle fingers, the pressure curve remained practically constant and the amount of pressure was very slight. Two of the subjects resorted to the expedient of pressing down the palm of the hand or the thumb in order to keep from pressing down on the pegs which supported the middle and little fingers. The pressure curve of the subjects that were instructed to relax was more regular and less in extent than the curve of those who were directed to keep their fingers rigid.

c. *Summary of Individual Reports*

The mental antecedents, or cues, that initiated the movement of the ring finger in each case were essentially the same as those reported in the previous series. The auditory cue, however, was reported more frequently than any other during this series. One reagent always innervated his finger so far as to be ready for the signal which seemed to touch off the movement. Another always had a visual image of the movement that he was about to make.

The mental processes that accompanied the movement of the ring finger varied. One reagent repeated mentally "up, down", which seemed to be his chief element of control. He was conscious of tactile sensations in the tip of the finger and sometimes reported sensations of strain in the metacarpal region near the metacarpo-phalangeal joint, but as a rule the kinaesthetic sensations did not rise above the threshold. Other reagents reported tactile, articular, and kinaesthetic sensations as elements of control. The non-moving fingers, during the learning process, were controlled by slight contraction of the antagonistic muscles.

Fatigue usually began to appear at the end of eighty to one hundred seconds when the subjects were required to move at the rate of one hundred and twenty times per minute; and when they were required to move for a longer period at that rate the subjects could not as a rule inhibit the movement of the other fingers. When only three or four minutes intervened between two tests, the inhibition of the little and middle fingers was not so good during the second trial as in the first on any given day. Articular sensations were usually localized in or near the metacarpo-phalangeal joint and as fatigue increased, tendinous and muscular sensations were felt in the metacarpal and carpal regions and in some instance sensations of strain were experienced in the fore-arm.

Automatism was acquired more rapidly by the subjects that were instructed than by those that were not instructed in the series described above. Twenty-five to thirty trials were required to gain complete automatism. The reagents that were instructed to hold their fingers rigid required about twenty per cent more trials than those that were instructed to relax.

2. GROUP II

a. *Right Hand Relaxed*

The six subjects of this group began the tests with the fingers of the right hand and were instructed to relax and move at the rate of 132 per second. As fast as control was gained, the rate was increased to a point where the subject could not inhibit the movement of the other fingers and practice was continued at the faster rate until control was gained. This process was continued until the subject gained control at the fastest rate possible, and then a rate faster than the subject could move and control the other fingers was required.

b. *Left Hand Contracted*

When control was practically perfect with the right hand relaxed, the subjects of Group II were given tests with the fingers of the left hand contracted. The rate was increased as stated above. Comparison of these tests with Group III, using right hand, fingers relaxed, is given below.

Group II gained control with fingers relaxed considerably faster than Group III, fingers contracted. This might seem to be due to the fact that Group II used the right hand while Group III used the fingers of the left hand; but when the instructions were reversed, the relaxed fingers gained control more quickly than those that were contracted. *On the whole, our experiments seem to show that control is gained more quickly when the fingers are relaxed during the learning process.*

As shown in Group I, the pressure curve becomes smaller with practice, and is very small after the subject has gained control and moves at a moderate rate; and when perfect inhibition is attained, the pressure curve becomes a straight line, showing a slight degree of pressure; but when the reagent is required to move fast enough to require effort, the pressure curve tends to increase in extent and to mark time with the moving finger. *When the inhibition is incomplete, pressure is always shown to be present in all normal tests.* Three of our subjects, that were acquainted with the object of our tests, avoided pressure on the tips of the fingers by pressing down on the palm of the hand.

c. *Effect of Rate on Pressure and Fatigue*

The effect of rate on pressure was marked. When the subject first begins to learn the movement, pressure is shown at each movement by the inhibited fingers, but the irregularity of the pressure curve gradually disappears by practice at the slower rate. By increasing the rate, the pressure curve rapidly increases, and tends to conform to the symmetry of the curve made by the moving finger. As the maximum rate is approached, the pressure curve suddenly increases in amplitude and conforms in time to that shown by the moving finger. When the rate is faster than that at which the subject can move the ring finger and inhibit the movement of the other fingers, the pressure curve becomes irregular both in amplitude and rate.

Speaking broadly, we find that as the rate increases in an arithmetical ratio, fatigue increases in a geometrical ratio. When the subject was required to move at the fastest rate possible, extreme fatigue occurred at the end of fifty or sixty seconds, and the amplitude of the curve was greatly reduced and frequently the subject was compelled to stop moving the finger because of exhaustion. After a given rate becomes well automatized, movement may continue for a considerable time without fatigue. A rate that is easy for one subject may be utterly impossible for a subject of a different type. When the subjects were required to 'contract,' fatigue was experienced more quickly than in the tests in which they were instructed to relax. In some instances the fatigue became so painful at the end of eighty or ninety seconds that the subject was compelled to stop. As a rule, the amplitude of the curve shown by the moving finger was less during contraction than during relaxation, and the pressure curve was greater.

3. Group III

a. *Left Hand Contracted*

Group III of the Pressure Curve Series began with the fingers of the left hand contracted and with a rate of sixty per minute; the rate was gradually increased as soon as the subjects gained approximate control, until a point was reached at which the subjects could go no faster and keep control of the non-moving fingers.

b. *Right Hand Relaxed*

Group III required approximately twenty per cent more time to gain automatism by the method of contraction with the left hand than Group II by the method of relaxation with the right hand. But when Group II used the fingers of the left hand contracted, and Group III, the fingers of the right hand relaxed, the former required twenty per cent more tests than the latter.

c. *Methods Compared*

All our tests accordingly seem to show that relaxation is the better method. In both cases, when change was made from right hand to left and from left to right and the method reversed, it required approximately but half as much time to gain control after the process had been learned by the fingers of the other hand. The effects of cross education were thus apparent even though the method was reversed.

TABLE SHOWING NUMBER OF TESTS REQUIRED TO GAIN CONTROL

GROUP II

	Right Hand Relaxed		*Left Hand Contracted*	
Subject	Rate	Tests	Rate	Tests
Cr.	132—208	31	60—200	20
B.	132—208	18	144—208	22
D.	132—208	12	144—208	10
F.	132—208	22	60—208	12
M.	120—192	28	60—184	19
R.	120—192	27	60—192	16

TABLE SHOWING NUMBER OF TESTS REQUIRED TO GAIN CONTROL

GROUP III

	Left Hand Contracted		*Right Hand Relaxed*	
Subject	Rate	Tests	Rate	Tests
Br.	60—208	35	60—192	16
Bu.	60—200	30	60—200	15
C.	60—200	38	60—200	19
Cu.	60—208	32	60—208	14
G.	60—184	26	60—192	14
W.	60—208	29	60—208	17

SERIES IV, FINGERS UNSUPPORTED

1. *Preliminary Statement*

The introspective reports from certain subjects in Series I, II, and III showed that tactile and pressure sensations due to the contact of the fingers with the table were factors of the control processes in each series. Another set of experiments in which the hand was unsupported except just above the carpal joint, was planned in order to test further the nature and value of the tactile and pressure elements as factors of the control processes. For this purpose a group of seven new subjects was selected. Both right hand and left hand series were given. During the right hand tests, the reagents were instructed to relax the muscles controlling the fingers; in the left hand tests, they were instructed to contract. The introspective reports of the subjects in the right hand finger movements are given below:

2. *Introspective Reports*

EYES OPEN

Subject J.

At the first, the experiment of moving the ring finger independently of the other fingers seemed impossible. The visual image came to the front first, showing how the finger would look when pushed down. Then the kinaesthetic sensations [or images] located in the muscle on the under side of the finger, seemed to pull the finger down. The other fingers moved down, too, to some extent, out of sympathy. Soon a keen sensation of fatigue on the inside of the palm and forearm made it nearly impossible to move the finger.

After a number of experiments the fatigue and kinaesthetic sensations almost disappeared. Part of the time the rhythm of the tactile sensations in the tip of the finger helped the control. Then the kinaesthetic and visual elements returned, and finally the movement became automatic.

Subject M.

Finger was innervated ready for the signal and so moved at the sound of the bell. Kinaesthetic sensations were felt in the volar side of first phalanx and in the metacarpo-phalangeal joint. Had a vague visual percept of the movement. Tactile sensations in the tip of the ring finger were elements of control. Was not conscious of middle finger, but conscious of tactile sensations in tip of little finger where it touched the thimble.

Subject P.

A visual image of the required movement immediately followed the signal. Visual perception controlled the moving finger at first, and then kinaesthetic sensations seemed to be the principal elements of control. The muscles of the other fingers were felt to be contracted, but they did not move. Watched the movement at first with reference to some spot on the table in order to regulate the distance. When the finger was not looked at, tactile and kinaesthetic perception guided the movement.

Subject S.

A visual-kinaesthetic image preceded the movement which was controlled by visual and kinaesthetic perception. Other fingers were out of consciousness most of the time. Arm became fatigued before the close of the test. The kinaesthetic sensations were localized in the volar side of finger from the tip of the metacarpo-phalangeal joint.

Subject A.

Kinaesthetic image always preceded the movement which was controlled by kinaesthetic perception. The other fingers dropped more and more out of consciousness. There seemed to be a peculiar connection between the kinaesthetic sensations and the rhythms of the time-marker and the motor.

Subject F.

Finger was innervated ready to move, and the signal simply touched it off. There seemed to be a tactile image of the ring immediately preceding the movement, but it could hardly be distinguished from the real sensation. Tactile sensations in the tip of the finger and kinaesthetic sensations in its volar side were the elements of control. Sensations of fatigue were felt in the hand and forearm. Other fingers were not in consciousness.

Subject G.

The initial cue was a visual-kinaesthetic image. Visual and kinaesthetic perception of the moving finger. The kinaesthetic sensations were felt in the metacarpo-phalangeal joint, and sensations of fatigue in the hand, wrist, and forearm. Other fingers dropped out of consciousness after control was attained. The kinaesthetic sensations seemed to be the principal elements of the control process.

3. *Summary of Introspective Reports*

The initial cue and the control of the moving finger do not differ essentially from those in the former series. More practice was required to learn to inhibit the movements of the other fingers than in the series in which the fingers were supported on the table. The pressure sensations were eliminated, but the tactile sensations produced by the thimbles continued to be elements of control, though not so valuable as those produced by contact with the table. The kinaesthetic sensations did not differ essentially from those described in the former series: they were localized chiefly in the volar side of the phalanges, and in the metacarpo-phalangeal joint.

The value of support and of the contact of the fingers with the table is shown by the fact that in the unsupported series, the number of tests required to gain control and inhibit needless movement was more than twice that necessary in the tests in which the hand lay flat on the table. It was difficult for the subject to hold the non-moving fingers in a given position, even when watching them.

The rate of two times per second was required of each subject, and caused fatigue when continued for over a hundred seconds. Sensations of fatigue were felt not only in the finger and in the metacarpo-phalangeal joint but frequently in the metacarpal and carpal regions, and even in the forearm. When the rate was made faster than two per second, control became more difficult. When the metronome was set at 180, the reagent in order to retain control dropped his movement back to 90, accenting each alternate tick. All the subjects acquired control up to 130, but above that rate control seemed impossible for them.

The average time required by the seven subjects to secure automatism was fifty tests, or twenty-five days, two tests being given each day. Two of the reagents acquired control in thirty tests, while two others required fifty, and one required seventy. The time required to gain automatism in the unsupported series is thus found to be approximately twice that of the series in which the hand is supported on the table, the subjects being instructed to relax in each case.

Fatigue naturally occurred more quickly when the subjects were required to move rapidly, and while they were learning the movement. The sensations of fatigue were felt first in the volar side of the finger in the first phalanx, the metacarpo-phalangeal joint, the metacarpals, the wrist, and the forearm, in the order named—extending from the finger toward the arm and shoulder as the fatigue increased.

The reagents were instructed to move the finger a distance of two centimeters as in the former tests. It was thought best not to move a longer distance in the unsupported tests than the supported ones; for in the latter it is not easy for the average subject to move a greater distance without straining the finger; and furthermore, the objective records are not easily preserved when the distance moved is more than two centimeters.

In the left hand tests the reagents were instructed to contract; control was gained in twenty tests, or two-fifths the time required for the right hand. In the uninstructed series, the left hand required only one-tenth as many tests to gain automatism as the right hand. This result was due presumably to the effect of central education. If this inference is correct, the method of relaxation is again shown to be better than that of contraction.

GENERAL SUMMARY OF PART I

1. All the flexor or extensor muscles controlling the movements of the members of a group tend to contract or relax simultaneously. On the physiological side there is a diffusion of the nervous impulse to the muscles whose contractions move the several members of the group; the motor discharge affects the muscular tonus of the whole organism. On the psychical side, there tends to be a diffusion of the attention to the several members of the group.

2. The problem of isolation of control in a group involves the task of draining the motor discharge into the nerve or nerves controlling the muscles concerned in moving the given member. The psychical phase of the problem involves the development, direction, and control of attention.

3. The inhibition of the movement of the other members of the group requires attention in the early stages of the process; the field of attention is the group and the focal point is usually the moving member during the learning process. When the subject learns to concentrate his attention wholly on the moving finger, the muscles controlling the other fingers become relaxed.

4. Inhibition of the movement of a part of the members of a group is due either to the contraction of the muscles controlling the inhibited members or to relaxation following upon non-attention to them.

5. Learning to relax is a necessary prerequisite both to voluntary movement and to non-voluntary inhibition. General relaxation is learned by learning to diffuse the attention—"by thinking

of nothing," as Professor James says. Local relaxation may be produced by fixed attention to some other part of the organism.

6. The development of voluntary control and the inhibiting and directing of the motor discharge are two phases of one total process.

7. During the learning process, the inhibited members exert a certain amount of pressure which gradually approaches zero as the movement becomes automatic.

PART II

INTERPRETATION OF RESULTS AND GENERAL CONCLUSION

At the risk of undue repetition of points already touched upon, we have brought together in the following paragraphs a few of the conclusions regarding the "cues," the "controls" and the essential aspects of attention and inhibition which we desire to emphasize.

1. *Initial Cue*

By initial cue we mean the immediate mental antecedent—sensation, perception, or image—of a movement. In so simple a case as that of the movement of a finger, it is not always easy to determine the mental processes that immediately precede the movement, for voluntary activity readily passes over in to mere automatism. But *during* the *learning* process, our tests show that the mental precursor of a *voluntary* act is characteristically sensation, perception, or image of some sort.

We tabulate below the results from six subjects of one hundred consecutive experiments on different days. The terms used in the table have their ordinary meaning as explained in Part I. In case one or the other element appeared more vivid, we have placed it first in the table.

Four of the subjects occasionally reported a general idea of movement as their initial cue, and five of them one or more times that the movement began automatically. The results given in the last two columns of the table seem to give some evidence in favor of the contention of Professor Woodworth and others that a naked thought can perfectly well perform the function of starting the motor machinery in action and determining the point and object of its application. But this occurs only after automatism has been acquired, and not during the learning process. It is probably fair to mention the fact that the writer when acting as subject, never reported his initial cue as a general idea or as automatic. This may be due to his prejudice to the theory, which prevented his perceiving the "naked thought," since all the other subjects that continued the work to the end seem to report its presence occasionally, but only after automatism had been gained.

The one hundred tests given in the table were taken after the subjects had been practicing daily for nearly three months. The accuracy of the introspections can hardly be questioned. The table of results tells its own story. It shows that almost any sort of a sensorial image or idea—and possibly any sort of an idea—may start the motor machinery after the process has become practically automatic.

THE INITIAL TABLE SHOWING CUE OF ONE HUNDRED TESTS OF MOVEMENTS OF THE RIGHT FINGER

One Test Being Given Each Day

Subject	K	V	A	V-K	A-K	A-V	G-I	Automatic
G.	65	8	18	2	2	2	0	3
Sn.	4	33	76	1	9	1	6	3
M.	17	29	40	2	2	0	6	4
P.	40	5	36	7	6	3	1	2
B.	5	10	20	41	18	6	0	0
S.	24	18	43	1	8	4	1	1

K Kinaesthetic
V Visual
A Auditory
V-K Visual-kinaesthetic
A-K Auditory-kinaesthetic
A-V Auditory-visual
G-I General Idea

2. *Control Process*

By the control process we mean the mental factors active in guiding the moving finger in rate, regularity, and amplitude of movement. During the learning process kinaesthetic, articular, tactual, auditory, or visual elements were present. One of these factors was usually more vivid than the others. One subject seemed to depend upon kinaesthetic perception to guide the moving finger but immediately interpreted the situation in visual terms, whether the eyes were open or closed. Another relied almost wholly on visual perception or visual image to guide the moving finger.

Visual control does not always mean a visual perception or a visual image of the moving finger. The subjects frequently controlled the movement of the finger by watching the recorder marking the curve on the kymograph. While moving the finger in the horizontal plane, one subject controlled the movement by watching the upright rods to which the thimbles were attached. When the subjects were blindfolded, they substituted the visual image for the visual perception.

The kinaesthetic factors were essentially the same whether the eyes were open or closed, except that the blindfold usually served to bring them into relief and thus make them more vivid. The kinaesthetic sensations were usually localized in the metacarpo-phalangeal joint and the first phalanx and metacarpal of the ring finger.

Sensations of strain were quite frequently localized in the wrist, the forearm, and in the region of the scapula. Only one subject reported vivid sensations in the region of the scapula.

Tactile perception was an important element of control even more than our introspections would seem to indicate. It enabled the subjects definitely to locate the position of the finger at the beginning and end of each movement.

The auditory element also played an important part, especially with movements in the vertical plane. The metal thimbles in coming in contact with the table at the end of each movement made a slight rhythmic noise. The subjects would frequently regulate their movements by the tick of the time marker. As we have said before, when a metronome was used, the subject moved his finger more easily.

The mental processes accompanying the movements depend upon the habits and mental types of the subjects. By voluntarily emphasizing one mental process it may be made the principal factor of the control process. But if the subject is left to choose his own method he will use that most familiar to him.

When the movements became well automatized, the subject could let his mind run to the ends of the earth without affecting the results. Reading, singing, or reciting seemed to give one subject better control of the finger movement.

3. *Attention*

In order to succeed, it was necessary for the subject to concentrate his attention on the idea of the movement to be made, making it as definite and clear as possible. During the first stages of the experiment it was found necessary to keep the non-moving members in the margin of the field of attention with the idea in mind that they must not be moved.

The kind of imagery to which the attention was directed depended as already indicated upon the mental type of the subject. The auditory, kinaesthetic, and visual in the order named were the more common.

The process of learning to attend to the moving member was found to be the key to our problem. The more exclusively the subjects could direct their attention to the movement to be made, at the same time dropping out of consciousness as far as possible the fingers not to be moved, the more likely was the desired movement and inhibition of movement to be perfect. While learning to attend to the moving finger, the subject learned to single out the various kinaesthetic sensations aroused by the movement. He learned to distinguish and localize the tendinous, muscular, and articular sensations. These elements once brought into the focal point of consciousness became clear and definite.

When the tests were continued for a longer period than eighty to one hundred seconds, the subject was unable to concentrate his attention on the movement and the consequence was loss of control. When the subject was fatigued either mentally or physically by overwork before the experiment began, poor results usually followed—due as a rule to oscillation of attention.

4. *Inhibition*

We observed three rather definitely marked stages of the inhibitory process in our problem:

1. The stage of contraction of the antagonistic muscles.
2. The stage of partial relaxation of the muscles.
3. The stage of complete muscular relaxation.

We use the term inhibition of movement as synonymous with prohibition or prevention of movement, being aware of the fact that the physiologist calls the first two stages innervation of the antagonistic muscles, and the third stage isolation of innervation.

During the first stage, the inhibition of the movement of the little and middle fingers was due to muscular and tendinous tension. When these two fingers happened to move, kinaesthetic sensations were usually localized in the first phalanges and in the metacarpo-phalangeal joints. The non-moving members were in the field of attention, but not in the focus unless the fingers moved. Attention being focused on the movement of the ring finger, consciousness of the other members became vaguer and vaguer from test to test. Finally the inhibited members became relaxed, and practically dropped out of consciousness. The consciousness of the non-moving members during the first stage consisted of visual images of the fingers or visual images of the record, kinaesthetic perception of them (in case they moved) and muscular, tendinous, and articular sensations.

The second stage is intermediate between the first and third. The muscles are partially relaxed and the muscular and tendinous sensations are vague and the process of inhibition is approximately perfect.

During the third stage, the fingers are relaxed and practically drop out of consciousness and during many of the tests dropped entirely out.

Tactile perception from the little and middle fingers reporting their position on the table and in the thimbles was an element of the inhibitory process. Frequently the subjects reported that the only consciousness that they had of the moving members was due to tactile sensations of the table.

Conclusion

It remains to summarize briefly the results of the various tests cited in the different parts of his paper. Part I attempted in the first place to throw into relief the mental processes utilized in initiating and controlling a special type of voluntary movement when no suggestions are given as to the method to be employed; and in the second place to determine, under like conditions, the mental factors involved in the process of inhibition. While the reagents were left free to move without any embarrassment, the mental type of each determined the mental factors utilized in initiating and controlling the movement. With practice, however, both the initial cue and the several factors of control could be varied at will by the reagent by voluntary direction of the attention; *e.g.*, to the visual, kinaesthetic, tactile, or auditory factors. But definite ideational or sensorial processes—or both—were present so long as the movement was voluntary; after it became automatic, the movement could be initiated by means of a very vague idea and the control process was chiefly below the threshold of consciousness. The degree of automatism differed considerably in the several individuals of the five groups of reagents.

In the distraction experiments of Section II, the problem was to test the effect of elimination of the visual factor, and also the effect of centering the attention on the tick of the metronome, on reading, or counting, during the movement. Those reagents that depended upon visual perception to control the movement learned quickly to substitute the visual image for the visual percept and were able to get on almost as well as they did with the eyes open. Sometimes the kinaesthetic percept was immediately followed by a visual image. When the reagent gave attention to the rhythm of the metronome, control was easy and good; but when attention was focussed on reading, control was poor. One reagent, however, had better control when required to read or count during the movement. In this particular case, finger movements were so thoroughly automatized that close attention to the fingers seemed to lessen the control.

The initial cue was always an auditory, visual, tactile, or kinaesthetic sensation or image, or some combination of these, during the learning process. Only after the movement had become automatized did certain of our subjects report a general idea of the movement as the initiatory cue.

During the learning process, the control factors of the moving finger were visual, tactile, kinaesthetic, articular, and auditory, one or more of these being more important than the others, according to the mental type of the subject. But as the movement approaches automatism, the subject relies on the kinaesthetic sensations localized in the metacarpo-phalangeal joint or in the first phalanx, to guide the moving finger. While the control factors may be varied to some extent by the will of the reagent, both observation and introspective reports show that the kinaesthetic element is the most important. Three of the subjects reported that they could control the moving finger better when they did not pay close attention to it, and especially when they did not watch its movements.

The effect of rate on control of the non-moving fingers showed great individual differences. For example, one of the reagents found difficulty in inhibiting the other fingers when the rate was slower than twice a second while another found it difficult to move at a rate faster than 84 per minute. As a rule, those reagents that take active part in athletics or command muscular dexterities like piano playing, can maintain control at a faster rate than others.

Fatigue was increased rapidly with the increase of rate. When the rate was made extremely fast for a given reagent, fatigue became painful before the expiration of a minute. But as we have stated in another place, twice a second was very fast for one subject while three times a second seemed easy for another.

The value of support and tactile sensations were shown in the "unsupported" series. The results of that series seem to show that when these elements are present the time of learning control is decreased about one half. The tactile element was important in gauging the extent of the movement and in keeping the non-moving members in position. While pressure seemed to be a means of resisting the overflow of motor discharge into the nerves controlling the muscles of the inhibited members, increased rate on the other hand increased the overflow and thus tended to prevent control.

In the distraction experiments of Series II, Part I, the reagent lost control for a time until he learned how to maintain the double process. As a rule attention went to the less automatized process. When the distraction was very effective, as in the case of reading an interesting story, the movement went on without conscious control. However, there were two exceptions to this rule: two of the reagents found it necessary to focus attention on some factor of the motor process, either the kinaesthetic sensations localized in the metacarpo-phalangeal joint, or the tactile sensations localized in the tips of the fingers—the latter being the more important factor in the inhibition process. Certain of the subjects relied on visual perception to inhibit the movement of the fingers, while certain others reported that visual perception positively hindered both movement and inhibition; the second group were composed, however, of persons whose finger movements were well automatized.

Series IV emphasized the value of tactile sensations in both control of movement and inhibition. The time required to gain complete control of movement and inhibition was approximately twice that of the other series. The elimination of the tactile and pressure elements from the inhibitory process, compelled the subjects to learn to rely on other factors; this took time. Relaxation and contraction were the methods used.

The pressure curve was rapidly reduced in amplitude by practice; but a sudden increase of rate greatly increased the amplitude of the curve. A sudden motor discharge thus seems to overflow into all the members of the group and causes or tends to cause them to move. This overflow is controlled by practice up to a certain rate, beyond which control becomes impossible; the speed cannot be maintained, the movement becomes irregular, the amplitude decreases, and inhibition becomes impossible. The limit of speed varied in the different subjects. Two were able to make almost perfect records at a rate of 208 per minute while others were not able to go beyond 192.

Relaxation of certain of the muscle groups is an essential part of the acquirement of control. The methods of attaining relaxation have already been discussed.

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Psycho-Motor Norms for Practical Diagnosis

A Study of the Seguin Form Board, Based on the Records of 4072 Normal and Abnormal Boys and Girls, with Yearly and Half-Yearly Norms

By
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Psycho-Motor Norms for Practical Diagnosis---

A Study of the Seguin Form Board, Based on the Records of 4072 Normal and Abnormal Boys and Girls, with Yearly and Half-Yearly Norms

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FOREWORD

The following contribution will interest particularly the following classes of readers:

First, psychological, educational, social and medical examiners who are engaged in the psycho-clinical examination of children by controlled laboratory tests. Psycho-laboratory examinations cannot yield trustworthy, objective, impersonal data unless the examiner has at his disposal reliable developmental age-norms for the different tests which he is using. The chief aim of this monograph is to supply psycho-motor age-norms by years and half-years for the form-board which is in most frequent use, for different types of children and grades of ability—for bright, normal, backward, feeble-minded and epileptic children.

Second, psychologists, educators, sociologists, penologists and physicians who are interested in the study of the mental differences between the two sexes, and between children of different ages and different degrees of capacity, and who are interested in determining the dependence of variability and practice upon the factors of sex, age and intelligence. This monograph furnishes data bearing on all these questions from an intensive study of one test.

Acknowledgments are made to the C. H. Stoelting Company, of Chicago, and to the Journal of Educational Psychology for their courtesy in permitting the use of cuts.

J. E. W. W.

April 1, 1915

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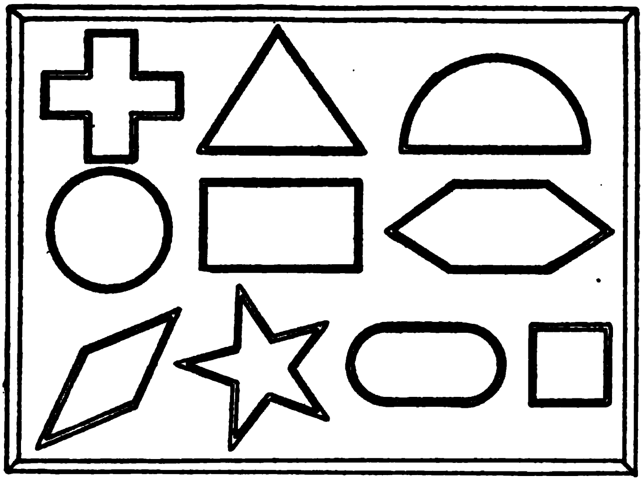
CHAPTER I

INTRODUCTION

Reasons for undertaking the investigation

The following investigation, begun in February, 1913, and concluded in June, 1914, was undertaken for the following reasons.

First, the conviction that the Seguin form-board, as modified by Norsworthy and Goddard, is one of the most valuable pieces of apparatus in the entire armamentarium of the psycho-clinicist for the purpose of grading psycho-motor development. An analysis of the form-board performance indicates that the form-board tests more than motor ability; that is, an individual's ability to grasp the different blocks and the accuracy and speed with which he can convey them to their appropriate recesses. It is also a test of "form sense"; that is, the ability to perceive visually or tactually, the differences between different forms, and to identify a set of solid forms with a corresponding set of depressed



THE MODIFIED SEGUIN FORM-BOARD

forms or recesses. Finally, the form-board, because it requires a rapid adjustment to a novel and complicated situation, is an excellent test of intelligence. It affords a controlled means of observing an individual's reaction characteristics in the presence of a new situation, and of measuring his capacity for making appropriate adaptive responses. Hence we are justified in speaking of the form-board test as a test of form perception, movement and intelligence[1]—that is, of psycho-motor development.

That there is urgent need for reliable motor or psycho-motor tests arises from the fact that it is inadvisable or dangerous to attempt to gauge a child's mentality purely by intelligence tests, particularly by means of the scales at present available. No system of intelligence tests in present use suffices for a comprehensive survey of mentality by means of tests, because practically all systems largely if not entirely ignore a phase of mentality which it is most important to estimate accurately, namely motor or psycho-motor capacity. We need comprehensive scales of motor capacity, no less than of intellectual development. Possibly we shall find it expedient eventually to combine a variety of motor and intellectual tests into one comprehensive psycho-motor scale. In any case, tests of *doing* should not be omitted in laboratory investigations of mentality.

Second, the conviction that the form-board cannot render its highest service, namely the grading of the degree of psycho-motor development (rather than merely the observation of reaction characteristics), unless thoroughly reliable normal age-norms are available. The paramount present-day need for all types of psycho-clinical examinations is the establishment of thoroughly reliable normal age-norms. Nothing will take the place of reliable age-norms established by standardized tests, neither insight, learning, experience nor technical skill. A psycho-clinicist without objective norms is like a sailor without a compass. Until such norms are available every examiner will depend upon his own subjective norms. Subjective standards are notoriously inconstant; they vary from person to person, and also with the varying conditions of the same person. A vast number of psychological tests, admirable in themselves, are of little value to the practical clinicist because of the lack of norms. Many of the form-boards are of limited value for this reason. Norms cannot be accepted on the statement, unsupported by definite figures, that "most of our twelve-year old children are successful in from one to three minutes." "Numerical precision is the soul of science" (Herschel), psycho-clinical diagnosis not excluded. The psychologist demands tabulated presentations of the data, showing exactly how many children have been tested, and the exact results obtained from children of different ages. Observations cannot be substituted for figures. The practical examiner to-day is handicapped not by a lack of psychological tests, but by a lack of reliable developmental norms.

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[1] Of course, the factor of attention is constantly involved, and the factor of memory during repeated trials.

Third, the keen realization that no thoroughly satisfactory normal norms were in existence for the modified Seguinian form-board. At the time the investigation was begun the norms available were based on the testing of only 250 children[2] from ages 5 to 12, or an average of 31.2 for each age. Sylvester's more extensive data[3] did not appear until some time after this investigation was started. The chief impelling motive for undertaking this investigation was the desire to supply the practical clinician with a set of reliable developmental norms of psycho-motor performance for this form-board for the growth period. The most valuable part of the contribution to the clinicist are the norms supplied for mentally normal and abnormal children.

[2] Goddard, Henry H. The Form Board as a Measure of Intellectual Development in Children. The Training School Bulletin, 1912, IX, No. 4.

[3] Sylvester, Reuel Hull. The Form-Board. The Psychological Monographs, 1913, XV, No. 65. The following form-board studies appeared after this monograph had been completed for publication: Eleven Mental Tests Standardized. Bureau of Analysis and Investigation of the New York State Board of Charities, 1915, No. 5. Pintner, Rudolf, and Paterson, Donald G. The Form-Board Ability of Young Deaf and Hearing Children. The Psychological Clinic, 1916, IX, 234 f. Young, Herman H. The Witmer Formboard. The Psychological Clinic, 1916, X, 93 f (another modification of the Seguin form-board. Gives experimental data for 1,474 boys and 1,375 girls). Young Mary Hoover. Correlation of the Witmer Formboard and Cylinder Test. The Psychological Clinic, 1916, X, 112 f.

Fourth, the feeling, long entertained, that scales of development arranged in whole-year steps are too inexact for the accurate grading of an individual, particularly during the early years of life when the individual is growing very rapidly. It seemed desirable to demonstrate, first, whether or not it was feasible or desirable to establish half-yearly form-board norms according to a scheme previously proposed,[4] by which no child could vary more than three months from his age classification. According to this scheme children whose ages ranged from 5 years 10 months (beginning of tenth month) to 6 years 3 months (end of third month) would be rated as six years of age; those who ranged between 6 years 4 months (beginning of fourth month) and 6 years 9 months (end of ninth month) would be rated as 6½ years; and similarly for the other age designations.

Furthermore, it seemed desirable to test the accuracy of the claim made that "in the teens one year makes less difference in intelligence than during the early years of childhood";[5] that "a unit of retardation" does not "mean exactly the same thing throughout the (Binet) scale;" that "the difference between, say, ages II and III is larger than between ages XII and XIII. A 20 year-old person who passes only age XII, and a 12-year old child who passes age IV, would both be rated as eight years retarded, but the eight years from 4 to 12 evidently represent a larger developmental difference than the eight years from 12 to 20. Moreover (and this bears on the Binet scale), the retardation is probably exaggerated for the few who pass Age XIII, because these few might have gone higher but there was no means of determining this by the scale."[6] It is only by extensive tests of individual traits that we can determine the correctness of the assumption that mental growth from age to age proceeds at a diminishing rate. The present research furnishes data for only the form-board test; a second series will include results from a dozen tests of intelligence administered to mentally normal and abnormal children in an institution and a public school system.

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[4] Wallin, J. E. Wallace. The New Clinical Psychology and the Psycho-Clinicist. Journal of Educational Psychology, 1911, 205 f. The Mental Health of the School Child, 1914, 110 ff.

[5] As before.

[6] Experimental Studies of Mental Defectives: A Critique of the Binet-Simon Tests and a Contribution to the Psychology of Epilepsy, 1912, p. 101.

Fifth, the desirability of confirming or refuting the assumption, or the alleged fact, that intellectual and motor development come to a standstill at from 12 to 15 years of age. This statement has been frequently made. Sylvester affirms that "the form-board is certainly of little value for testing individuals who have the ability of that age (14) or of a year or two younger."[7] "It is not worth while to establish norms for those above fourteen."[8] "In form perception and motor ability, as they are required in this test, there is practically no gain after a point somewhere about the age of twelve."[9] Unfortunately Sylvester has omitted to give facts in support of his statements. Reference to our tables will show that there is a gain of 3 sec. between ages 12 and 17, manifestly a worth-while improvement, in view of the fact that there is a consistent, though small, gain for each age between 12 and 17—and presumably somewhat beyond 17—and in view of the fact that the gain for these five years amounts to as much as 35% of the gain for the five years from 7 to 12. A recent writer makes the broad assertion—no evidence is supplied—that the development of intelligence "comes practically to a stop at the age of fifteen." If by intelligence is meant the general ability that an individual shows in adapting himself to a set of new problems, or old problems modified, calling for perception, comparison, discrimination, memory, retention, then experimental data in hand indicate that the assertion is unsupported by facts, at least so far as concerns a number of mental traits.

Some writers possibly have fixed the limits at 12 or 13 or 15, because Binet's tests in the 1908 scale ceased at 13 and his childhood tests in the 1911 scale ceased at 15. Binet's scales, however, stopped at those points because Binet arbitrarily stopped them there, and not because he had demonstrated that the growth in intellectual capacity stopped at 13 or 15. The only way to

[7] P. 8.

[8] P. 12.

[9] P. 37.

determine how far intellectual capacity increases is to administer numerous tests of different traits under exactly the same conditions to normal children of different ages, continuing with older and older children until no improvement occurs. Binet did not attempt to do this. It has been attempted fairly intensively in the present research on the form-board up to and including age 17, and less intensively but more extensively in a set of twelve intelligence tests covering children from 7 to 17 years of age.

Sixth, the desirability of supplying normal norms of variation in addition to age-norms of central tendencies,[10] so that it may be possible to determine an individual's degree of variation in terms of the appropriate mathematical function (M. V. and $\frac{\text{M. V.}}{\text{A.}}$) as well as in terms of age-scores, or so that it may be possible to determine the degree of variation from age-standards that may be considered normal.[11]

Seventh, the desirability of ascertaining whether or not there are appreciable sex differences in psycho-motor development, as measured by the form-board, for children of the same age. Such differences had appeared in an earlier work on epileptics,[12] not only in the speed of motor reaction as determined by the form-board,[13] but in the speed of naming colors,[14] of reading,[15] and of uttering detached words,[16] as well as in ability to retain the contents of a read selection,[17] the ability to make voluntary motor contractions,[18] and to maintain steady body balance;[19]

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[10] The Present Status of the Binet-Simon Graded Tests of Intelligence. Alienist and Neurologist, 1912, May; Experimental Studies of Mental Defectives, 42, 104f. The Mental Health of the School Child, 197, 205, 226.

[11] Measures of variability are provided for all the form-board data compiled from the writer's own experimental researches.

[12] Eperimental Studies of Mental Defectives. Chapter III.

[13] Table XIII, and p. 73-76, 99 (males superior).

[14] Table X and p. 67-69, 99 (females superior).

[15] Table XI and p. 71-72, 99 (females superior).

[16] Table XV and p. 77-81, 99 (juvenile females superior to adult males, adult males superior to adult females).

[17] Table XVII, and p. 82, 99 (males superior).

[18] Table XIX, and p. 87, 88, 99.

[19] Tables XXII and XXIV, and pp. 91-92, 99.

and in an earlier investigation of public school boys and girls, in the rate of perception and manual reaction, of memorizing and of forming free and controlled verbal associations.[20]

Sylvester has come to the conclusion that "sex differences are of no importance in the form-board test."[21] His own figures, however, show that the boys among the backward children decidedly surpassed the girls (average time 20.3 sec. as against 26.2 sec.[22]), while the boys among normal children were also a trifle superior to the girls.[21] He assumes that if there had been as many girls as boys in the backward classes tested "their form-board records would have been more nearly equal."[22] Our results will show that the boys in this test surpass the girls, particularly in the normal group.

Eighth, the desirability of making an extensive study of the effect of repetition upon the form-board performance, particularly as affects the difference in the speed of reaction between the first, second and third trials, and between the averages for each of these and the averages for the best score in the three trials. It is essential to have this information in hand, in order to determine whether the practice is justifiable of taking the best record out of three trials as the correct or representative index of the individual's efficiency. Owing to the appearance of Sylvester's study this feature of the investigation has not been worked up as fully as was originally contemplated.

Ninth, the desirability of ascertaining whether the motor reaction rate differs for bright, average and dull public school pupils of the same age, as well as for normal and abnormal (feeble-minded and epileptic) children of approximately the same mental ages.

[20] Experimental Oral Euthenics: An Attempt Objectively to Measure the Relation Between Community Mouth Hygiene and the Intellectual Efficiency and Educational Progress of Elementary School Children. Dental Cosmos, 1912, April and May. (The boys excelled in the memory, spontaneous association, antonym and addition tests; the girls in the perception-reaction test.) Incidentally attention may be called to a qualitative sex-difference in spelling efficiency: Spelling Efficiency, in Relation to Age, Grade and Sex, and the Question of Transfer, 1911, Chapter III.

[21] As before, p. 38.

[22] As before, p. 16.

Nature of the data studied

This study is based on the following data:

First, the form-board records from the cases clinically examined by the writer in the psycho-educational clinic of the School of Education of the University of Pittsburgh and the Psycho-Educational Clinic of the St. Louis Schools (Tables XVI to XLVII). These cases will be referred to as the *clinic* cases. They include 313 boys and 133 girls, or a total of 446. Not all the cases which were examined are included, some because the records happened to be defective in one way or another, some because the child's condition was complicated by deviations other than intellectual (*e. g.*, blindness or plegia), and some because they were unable to do the test (cases with a mentality of 1, 2 and 3 years). No other selective factors were operative.

These cases were clinically classified into the following groups, the figure following each group indicating the per cent of the 446 cases so classified; idiots (.44%); imbeciles (11.9%); morons (14.8%); border-line (12.5%); backward (32.2%); retarded (13.9%); normal (10%); and bright (4%).

The clinic cases have been tabulated in two ways; first, by mental ages according to the B.-S. (Binet-Simon) scale; and, second, by chronological ages according to the calendar age of the subject. Practically all of the B.-S. tests, as well as the form-board tests, given to these cases were administered by myself and not by assistants or teachers. The B.-S. tests were given exactly as previously given to epileptics.[23] In classifying the cases into idiots, imbeciles, morons, etc., I did not always, however, rigidly adhere to the conventional mental age limits of the Binet scale: idiots, 1 to 2 years; imbeciles, 1 to 7; and morons, 8 to 12. As explained elsewhere[24] the classification is based on the ensemble of available hereditary, developmental, physical, pedagogical, social and mental data bearing on each case. The average chronological and Binet age is given in the first two columns on the left hand side of each table. In both cases fractions of a year are expressed in decimals.

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[23] See my Guide, in Experimental Studies of Mental Defectives, p. 116f.

[24] The Mental Health of the School Child, 1914, pp. 144ff.

The sub-classifications here used will make it possible to discover the psycho-motor differences between subnormal, normal and supernormal children of approximately the same mental age as well as the same chronological age.

Since all except 14% of these cases are classified as below normal, it will be convenient to also refer to them as the *subnormal* group, in distinction from the following group of *school* cases, which may be referred to as the *normal* group, although not all in the first group are subnormal, nor are all the subnormal feeble-minded, and although not all in the second group are normal.

Second, the form-board records of 699 boys and 730 girls, total 1429,[25] who were specially examined in four public elementary schools in Pittsburgh, Pa. (Tables I to XV). All the pupils except "about one hundred in the Bellefield school and about two hundred and fifty in the Holmes school" were given the test. The pupils who were not tested evidently represent an unselected group. They include the children who were absent while their classmates were being tested, and about half of the kindergarten children in the Holmes school. Only a selected number (115 pupils) of the brighter pupils in the Colfax school were tested.[26] Among these cases, however, are included 18 young children who were attending the School of Childhood of the University of Pittsburgh, and 13 young children examined in baby clinics. This entire group of children will be referred to indiscriminately as the school cases or normal children. We are justified in calling these children normal, because the selection yielded 75% of "average" or normal cases (538 each boys and girls, total 1076), and an approximately equal number (12%) of "dull" (90 boys, 93 girls, total 183) and "bright" pupils (71 boys, 99 girls, total 170). The total number of girls is only slightly in excess of the number of boys.

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[25] The number of cases in the half-year classification is 1,480 (722 boys and 758 girls).

[26] I am under obligations to Principals J. A. Hollinger, Margaret A. Frew and Laura V. Steel for courtesies extended in connection with the research. Miss M. Marguerite Apgar has rendered valuable secretarial service.

The selection of the "brighter" pupils from the Colfax school, and the classification of the pupils in the Bellefield and Holmes schools into "bright," "average" and "dull" was made by the teachers and principals. They were asked to base their estimates on the pupils' intellectual ability, pedagogical proficiency and age-grade classification. No claim is made that this classification of the pupils according to ability is absolutely accurate. It is probably about as accurate as the usual classifications made under similar conditions. It is of interest to note that while the percentage of pupils classified as average in ability is almost the same in Bellefield (83.6%) and Holmes (81%) schools, the percentages of bright and dull are about equally divided in Bellefield (7.6% bright and 8.6% dull), while no pupils are recorded as bright in Holmes and 18% are recorded as dull. This may be due to the fact that a more rigid standard was followed in Holmes, or to the fact that the Bellefield pupils come from a higher social level. The 115 children reported as among the "brighter" pupils in the two Colfax schools constitute 16% of the entire attendance at the time of the testing—268 pupils in Number 1, which is situated in a poor quarter, largely populated by a foreign element, and 446 pupils in Number 5 (now Wightman), which is situated in one of the best residential sections in the city.

It is probable that the distribution of ability among our cases from the Bellefield and Holmes schools, where the cases were unselected, would be typical of urban communities inhabited by skilled and unskilled laborers, tradesmen and professional people, and containing schools without segregated rooms for feeble-minded children. These schools were provided with "ungraded classes" designed for coaching slow or retarded pupils, but not, theoretically, for feeble-minded. These ungraded pupils were included in the present survey.

Some of these pupils had been clinically examined by me, in the clinic of the School of Education of the University of Pittsburgh, and found to range from imbecilic to approximately normal children. While no data are available as to what percentage of the "dull" pupils are feeble-minded, the number would constitute an insignificant ratio of the total number of cases examined.

All the School of Childhood children (9 boys and 9 girls) were rated as average by one of the assistants in the school, while all of the baby clinic cases (3 boys and 10 girls) were rated as bright on the basis of their records in the Perfect Baby Clinic and Perfect Baby College (conducted by Mrs. Frank De Garmo, the originator of the Better Baby contests), in which they were clinically examined by the writer in St. Louis in the fall of 1914. The writer was requested to make the final selection of the prize winners, hence the cases examined by him included only the candidates for highest honors. These candidates represented the cases which had survived after a process of elimination, based on psychological, medical, dental and anthropometric examinations, affecting 338 babies, and may, therefore, be regarded as a selection of superior merit. Only the records of the "babies" who succeeded in doing the test are tabulated in the tables. Many between one and two years of age failed to perform the test within the limits of time that could be allowed them.

All the school cases were tested in vacant rooms or in the principal's office of the school buildings, while the prize candidates were tested in quiet rooms connected with the baby clinic or baby college. In the testing of the school cases I was greatly assisted by Mrs. A. W. Field and Miss Eva Webb, the latter likewise rendering invaluable assistance in helping me with the computation of some of the records.

Third, the form-board scores of institutional cases of epileptics previously clinically examined by the writer (308 cases: Page 35).[27]

Fourth, the form-board scores of other investigators (Table XLIX.) This includes 1588 normal children examined by Sylvester[28] ("no especially backward or peculiar children were included") and 250 children examined by Goddard.[29] Nothing is stated regarding the distribution of the mental ability of Goddard's cases. Neither of these writers grouped the children according to sex. I am including these cases for two reasons;

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[27] Experimental Studies of Mental Defectives, 62f, 73f, 96f, 97, 106.

[28] As before, 46, 53.

[29] As before.

first, in order to make the data readily accessible for comparative study—the results are therefore tabulated separately in Table XLIX—and, second, in order to afford a larger number of cases on which to base whole-year norms (3253 cases)—the averages are therefore merged in the final column of the table. Clinical workers who desire to use this form-board can choose between four different series of whole-year norms, besides the half-year norms which are given for boys and girls separately and combined in Table XLVIII.

The method of testing the school and clinic cases was uniformly as follows: The children, brought into the testing room one by one,[80] occupied a standing position directly in front of the table containing the form-board. The side of the form-board containing the star was always nearest the child. The blocks were quickly removed from their recesses by the experimenter and thrown indiscriminately in a compact pile invariably near the edge of the form-board which was at the child's right, the child meanwile watching the operation (and in some cases assisting in the removal).[81] Then the child was told to replace the blocks in their proper recesses *just as fast* as he *possibly* could, using only one hand. The second time he was urged to replace the blocks faster, and the third time still faster. Invariably the children were stimulated to put forth their best efforts. The experimenter did not initially replace any of the blocks, thereby actually showing the child how to proceed. However, in the case of a few of the babies who made no attempt to grasp the blocks, the experimenter placed a block in the child's hand and told him to place it in the right hole. Exactly the same method was earlier used in testing the epileptics except that the blocks were piled up near the middle of the side of the board farthest from the subject, so that the blocks would be equally accessible to the two hands—the method later adopted by Sylvester. This earlier method was abandoned because the subjects were obliged to reach farther for the blocks, and particularly because they were obliged to reach across the form-board, with the result that the arm would sometimes obscure the recesses, or the body would incline too far forward, or a short subject would find it difficult readily to reach the blocks.

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[80] They were brought in one by one so that they might not be influenced by one another's successes, failures, or peculiar modes of attack. One of the assistants, however, did not strictly adhere to this condition, sometimes permitting children to be sent to the room in groups of two or three, in order to expedite the passage of the children.

[81] In my routine clinical examinations the child is invited to assist me in removing the blocks. Whipple places the blocks in a definite order on the table and requires the child to replace them in a prescribed order: Whipple, Guy Montrose. Manual of Mental and Physical Tests. Part I, 1914, p. 298. I have found various disadvantages and no very marked advantages in this standardized procedure.

The record of the three trials included, first, the time required to replace the blocks, recorded in fifths of a second by means of a stop watch. The watch was started the moment the child's hand touched the first block, and was stopped the moment the last block was in place. No "ready" or "start" or "go" signal was used, unless the child failed to start after the blocks had all been removed and he had been urged to do his best. Second, a complete record was made of every move made by the child's hand in attempting to replace the blocks—a quantitative record of the number of movements made and a qualitative record of the errors committed. Each block and its corresponding hole were assigned a fixed number. Thus 1 was the Maltese cross, 2 the triangle, 3 the half moon, 4 the disc, 5 the oblong, etc. In order to economize space on the record sheet the following method of recording the results in one or two horizontal lines has been found very satisfactory. When the block is properly placed the first time the number of the block is recorded followed by a period. Thus 5. 2. 4. indicate that blocks 5, 2 and 4 were placed directly in holes 5, 2 and 4. A dash (—) shows that the block indicated by the figure preceding the first dash was placed in the recess indicated by the figure following the dash. Thus 6—7—6. 10—4—9—10—5—10. show that block 6 was placed wrongly in recess 7 and then properly in recess 6. Block 10 was first placed in recess 4, then 9, then 10, then 5, and finally properly in 10. A number followed by a dash and cipher (0) indicates that the block was grasped, then perhaps rapidly moved over the board without being placed in any hole, and then discarded.

An X indicates that the block was left on top of a recess but not fitted in. Thus 5—7X 6—6X show that block 5 was left on top of recess 7. Block 6 was left on top of recess 6. A line drawn vertically through a numeral indicates that the corresponding block was removed from the position in which it was previously placed but was not placed in any recess. The following is a typical record 10. 8—1—8. 5. 7—2—6—7—6—7. 3. 5. 9—0. 4. 9. 1. 2. Interpreted: 10 properly placed at once; 8 placed in 1, then in 8; 5 correctly placed; 7 placed in 2, then in 6, then in 7, then in 6, then in 7; 3 correct; 5 correct; 9 grasped but not placed in any hole; 4 properly placed; 9 correct; 1 correct; and 2 correct.

No attempt will be made in this monograph to analyze, quantitatively or qualitatively, the procedure used in replacing the blocks, although complete data are available for such analysis. My results, however, agree, in the main with Sylvester's findings.

The original tables, based on the averages of all the records of the reaction rates, are reproduced in complete form in Chapter VII, partly because it is here impracticable to detail all facts contained in the tables, and partly because investigators are constantly hampered in their attempts to utilize previous studies for comparative purposes because of the inadequacy of the data supplied. Thus it will be possible for subsequent workers to compare in detail their results with mine,[32] to retreat my data mathematically by different statistical methods, and to average my results with their own, so that eventually we may obtain a set of form-board norms based on many thousands of cases.

Explanation of terms and abbreviations

B.-S., indicates Binet-Simon. The B.-S. ages are always given in Roman figures.

The three successive replacements of the blocks in the form-board are referred to as the I, II and III trials.. The Sh. columns in the tables contain only the averages of the subject's shortest records, the best records in the three trials. These averages are referred to as the shortest (or Sh.) record or score.

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[32] Although the original tables appear in complete form, 29 tables derived from a retabulation of the original data do not appear here at all, but only the general averages or the generalized results. To have included all the derivative tables would have unduly increased the length of the book.

The word ***subnormal*** will be used in the generic sense to include all cases classified as below normal: the retarded, backward, seriously backward, border-line, and feeble-minded. The expression *mentally deficient* is objectionable because some writers use it as synonymous with subnormal, in the sense above defined, while others use it as equivalent to feeble-mindedness. It seems best to use this word in the generic sense, as there are various degrees of mental deficiency which do not amount to actual feeble-mindedness.

Sec., indicates second or seconds.

CHAPTER II

THE INCREASE OF PSYCHO-MOTOR CAPACITY WITH CHRONOLOGICAL AND MENTAL AGE.

Normal children (school cases), classified according to chronological age by half-year steps

We shall consider the differences between the half-yearly averages for the boys and girls separately and combined. The analysis will likewise cover the results separately for the bright, average, and dull groups, in the first, second, third and shortest trials. The tables (I to XV) are somewhat incomplete in ages 4, 16 and 17, but still furnish data for 152 separate comparisons. The differences in these tables will be computed only between the lower and higher half-years of the same age classification: *i. e.*, between 4 and 4½ years, between 5 and 5½ years, etc. On the other hand, the differences in Table XLVIII will be computed between each successive half-year designation, thus: between 4 and 4½, between 4½ and 5, between 5 and 5½, between 5½ and 6, etc. In this table no account is taken of the difference in the intelligence of the pupils, and the results represent only the averages of the best records (Sh.) of the three trials.

That it is feasible to establish half-yearly form-board norms admits of little doubt. It is found that, taking the gross results for all ages and classifications in Tables I to XV, there is an improvement from half-year to half-year in 108 instances (71%), a loss in 41 instances (27%), while the results were the same in three instances (2%). The gross gains for all the ages and classifications amount to 210.1 seconds while the gross losses amount to 94.7 sec., a net gain of 115.4 sec., or an average gain per half-year of .75 sec. That there should be any losses at all is undoubtedly due to the fact that, although the tables are based on 1,480 cases, only a few cases are included in some of the minor groupings. Therefore one or two exceptional cases may readily disturb the normal progression. With a large number of cases there would probably be no exceptions to the rule.

In Table XLVIII (final half-year table), the boys' averages show 21 gains and 5 losses, the girls' averages 17 gains, 8 losses and 1 equal and the averages for both sexes 20 gains and 5 losses. Here the average amount of gain from half-year to half-year (subtracting the gross losses from the gross gains and dividing by the number of counts) amounts to .91 sec. for the boys (age 16^{10}-17^{8} missing), 1.0 sec. for the girls (age 16^{4}-16^{9} missing), and 1.0 sec. for the averages for the boys and girls (exclusive of ages 16½ to 17½). If we exclude the large difference between ages 4 and 4½ (8.9 sec.), which is entirely exceptional, the average gain per half-year amounts to .70 sec.

For the lower ages, 4½ to 10 inclusive, the average gain per year, 1.03 sec., is more than three times as large as the average gain for the higher ages, 10½ to 16, .33 sec., both sexes combined. Evidently the half-year differences below 4½, were data available, would be proportionately larger than the differences for the ages between 4½ and 10, as is indeed suggested by the large gain between 4 and 4½.

The improvement with each ascending half-year is greatest for the average pupils and least for the dull. This may be shown, first, by the percentages of gains, losses and equal scores for the bright, average and dull pupils, which are as follows (the per cents are the averages of the per cents in the first, second, third and shortest trials):

	Per cent of gains	Per cent of losses	Per cent of equal scores
Bright:	65	30	4
Average:	89	8	2
Dull:	54	45	

The results are the same if the comparison is limited to the gains and losses in the column containing the shortest scores:

	Per cent of gains	Per cent of losses
Bright:	69	30
Average:	92	7
Dull:	54	45

It may be shown, second, by the average gains in seconds for each half-year made by the bright, average and dull pupils, which are as follows (these are the averages for all the trials, I to Sh.):

Bright	Average	Dull
.62	1.31	.17

The average pupils gain with each successive half-year more than twice as much as the bright pupils and about eight times as much as the dull ones. It is quite evident that it is fundamentally important to know when prosecuting investigations for the purpose of establishing norms whether the children tested are bright, average, or retarded, a consideration previously urged in criticism of Smedley's anthropometric norms.[1]

Why do the dull pupils show so little improvement with each ascending age? Is it because they mature earlier, as suggested by Bolton,[2] and having become prematurely old, they naturally improve less with increasing chronological age? If this hypothesis were true, we should expect the dull pupils to do relatively better in the early years than do the bright or average children. But there is no conclusive evidence that this is the case. The average gain per half-year (based on the Sh. scores) for the dull for the years 5 to 9½ amounts to .18 sec., and for the years 12 to 15½, .20 sec., which shows a smaller gain in the lower than in the higher years. The corresponding figures for the average pupils is 1 sec. and .44 sec., and for the bright —.22 sec. (loss) and .84 sec. It is clear that the improvement was greater in the lower ages than in the upper ages for the average pupils only. The percentages of ages in which there were gains in the lower group were, respectively, 60, 80 and 40 for the dull, average and bright pupils; while the corresponding per cents for the upper group were 40, 100 and 80. The dull gained more frequently in the lower group of ages, and the bright and average in the upper group.

A second supposition is that the dull manifest their dullness early and fail to outgrow it. I believe this is the correct explanation. It is, theoretically, improbable that young dull children (except such types as the cretins, or mongols) are prematurely old or senile in bodily development, as determined by the creteria of anatomical and physiological age. At any rate, this hypothesis must be verified by objective studies before it can be accepted as a fact. On the other hand, statistical investigations of retarded children have shown that many of them progress at a retarded rate throughout their entire school course.[8] Allowing for occasional exceptions, we may say that pupils who are genuinely or inherently retarded during the early years of childhood will be retarded during the middle and later years of childhood, and, by a parity of reasoning, during adulthood.

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[1] The Mental Health of the School Child, 1914, p. 108.

[2] Bolton, T. L. The Relation of Motor Power to Intelligence. American Journal of Psychology, XIV, 1903, p. 615f.

This conclusion is of prime importance to the geneticist. It suggests that the hereditary capital bequeathed to each individual from ancestral strains cannot be radically altered by environmental forces. Nature is more potent than nurture in determining the limits to an individual's capacity. I am, of course, speaking of potentials, or of inherent capacity, in contradistinction to acquisition or attainment. Of course, how a person actually invests his inherited capital, and what he accomplishes with it, depends upon environmental factors. But no amount of training can overcome defects in the original endowment.

The improvement with each succeeding half-year is clearly greatest during the second trial. This is shown both by the average per cents of gains, losses and equal scores and by the average amount of improvement in seconds in each of the trials. The following per cents represent the combined averages for the bright, average and dull pupils for all ages:

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[8] Wallin, as before, p. 118; see references to Gayler and J. Since the above was written I find the following corroborative evidence from an analysis of the B. -S. records of normal and mentally defective children: "The mental excess of normal children is, on the average, 2 months' defect, and it increases by about a month per year of life. But the mental defect of the mentally defective children is, on the average, 3 years, and they lose about 5 months per year"—Pearson, Karl. On the Graduated Character of Mental Defect and on the Need for Standardizing Judgments as to the Grade of Social Inefficiency which shall Involve Segregation. Questions of the Day and of the Fray, 1914, IX, 44.

	Per cent of gains	Per cent of losses	Per cent of equal scores
I trial:	63.	33.3	2.6
II trial:	72.	27.	0.
III trial:	70.	26.	2.6
Sh. scores:	71.6	27.3	0.

The average gain in seconds with each half year is as follows for each trial: I, .35; II, 1.37; III, .86; Sh., .81. The age improvement is about 4 times as large in the second trial as in the first, over one and a half times as large in the second as in the third trial, while it is about the same for the third trial and the shortest scores.

The fact that the increase with age is greatest during the second trial may appear to possess merely academic or theoretical interest, but it is of great practical moment. It means that we cannot adequately bring out age differences in quantitative psycho-motor tests (or at least in this test) by merely giving children one test. Differences of capacity between children of different ages come out more clearly after the first trial. Here the age difference is larger during the second than during the third trial and, presumably, it is also larger during the third than during the fourth trial. How far the difference would continue beyond the third trial needs to be experimentally determined.

Normal children (school cases), classified according to chronological age by whole-year steps.

The average difference between the averages for each successive whole-year for ages 4 to 17, inclusive, in Table XLIX which contains the averages of the shortest records only, amounts to 1.4 sec. for the boys, 1.3 sec. for the girls and 1.4 sec. for both sexes. There is a decrease in time in each successive age with one exception for the boys (ages 12 and 13 being equal), one for both sexes (a loss of .1 sec. in age 13), and two for the girls (ages 12 and 13 equal, and a loss of .2 sec. in age 15). The greatest amount of improvement between any two ages is 3.2 sec. for the boys (between 4 and 5) and 3.4 sec. for the girls (between 5 and 6) and 3.3 sec. for both sexes (between 5 and 6).

The ages in which the gain is the smallest is 10 (.5 sec.), 12

(.4 sec.) and 13 (equal) for the boys, and 9 (.9 sec.), 13 (loss of .1 sec.), 15 (.2 sec.) and 16 (.5 sec.) for the girls.

The gross amount of loss compared with the gross amount of gain from year to year is entirely negligible. For the boys there is no loss while the total gain for all ages amounts to 18.5 sec.; for the girls the total loss is .2 sec. compared with a total gain of 18.0 sec.; and for both sexes the total loss is .1 sec. compared with a total gain of 18.3 sec. With a larger number of cases in some of the ages the gain would very probably have been consistent from age to age.

The gain is very much larger for the younger years, amounting for the lower ages (4 to 10, inclusive) to 2.2 sec. per year for the boys, 2.4 sec. for the girls and 2.3 sec. for both sexes, as compared with .56 sec. for the boys, .50 sec. for the girls, and .51 sec. for both sexes for the higher ages (11 to 17, inclusive). It is somewhat less than one-fourth as large in the higher ages as in the lower.

The amount of gain does not decrease regularly from age to age, as is seen from the following gains in seconds for each successive age from 4 to 17 for both sexes (- signifies a loss instead of a gain): 3.0, 3.3, 2.8, 2.8, .9, 1.2, 1.1, .9, -.1, .9, .2, .5 and .7. The largest gain for both sexes in any one year after age 11 amounts to .9 sec. (ages 12 and 14).

Instead of using the figures in Table XLIX (the shortest scores) as the index of yearly improvement, we may combine the averages of I, II, III and the Sh. scores for both sexes in each age in Tables I to XV. The first line in the following tabulation gives the general averages for each age (averages of I to Sh.), and the second line the improvement in seconds from age to age:

Age:	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Time, sec.:	34.9	30.8	25.3	21.9	18.4	17.1	15.7	14.7	13.5	13.6	12.7	12.4	12.3	10.9
Improvement:		4.1	5.5	3.4	3.5	1.3	1.4	1.0	1.2	–.1	.9	.3	.1	1.4

It is seen that there is an improvement from age to age, with only one negligible exception. The total amount of gain amounts to 24.1 sec., and the total loss to .1 sec. The average amount of improvement per year amounts to 1.9 sec. For the lower ages (4 to 10) it is 3.2 sec., and for the higher ages about one-fifth as much (.69 sec.).

The results from comparing the combined averages (I to Sh.) agree with those based on the averages for the shortest scores only, but the improvement in the former case is greater and more uniform. That the improvement does not diminish regularly from age to age may be due to the limited number of cases in some ages (limited, that is, in the sense that there are not several hundred in each age).

While the improvement in the higher ages is not large, it is positive in all ages, except age 13. Since it has been seen that the abler children do better than the less able, and since the children in ages 15, 16 and 17 were pedagogically retarded and also presumably somewhat mentally retarded (the number actually classified as dull is given on p. 31), it would follow that had there been more average and bright and less dull children in these ages the improvement would have been larger. At any rate, the tests furnish little warrant for the assumption that psycho-motor capacity, as measured by this form-board, attains its complete development at age 12, or even at age 14, for the reaction rate grows shorter up to and including our highest age, namely, 17. The age beyond which no improvement will occur in this test has not yet been experimentally determined.

I would suggest the thought, however, that it may be advisable to establish bi-yearly norms for this test after age 12. Our results show that a common norm is practicable for ages 12 and 13 (which give the same results), 14 and 15 (a negligible difference between the averages for the two sexes), and 16 and 17 (the increased difference here may be of no import—because of the few cases included).

Just as we would urge the advisability of establishing bi-yearly norms for the adolescent years, our results show the necessity and practicability of establishing semi-yearly norms for the lower ages and yearly norms for the middle ages. An analysis of the half-yearly and yearly data indicates that it is feasible to establish semi-yearly form-board norms up to about age 8, yearly norms from 8 to about 12, and bi-yearly norms from 12 to 17 or beyond.

The probability is very high that it is possible and desirable to construct norms for any other kind of motor performance or any other kind of mental trait in accordance with the above scheme of graded units, although the boundaries of the different units may not precisely correspond with the above divisions. Various tests conducted at baby clinics indicate that the steps can be made still smaller during the first year or two of life. My present impression is that age-scales which include a large variety of tests constructed in accordance with the above principle are of more value to the practical clinician than the rating of individuals on the basis of the accumulation of points (Huey's proposal).

It should be emphasized, however, that in order to construct maximally satisfactory graded scales, it is essential to administer the same tests under precisely the same conditions to normal children ranging in years from those who are so young or immature that they can barely perform the test in question and extending to children so old or mature that they fail to show any improvement. When data have been thus gathered we shall be able to construct semi-yearly, yearly and bi-yearly norms, or norms for any other steps that may be found desirable. If these norms are based on a sufficiently large number of normal children, and if a sufficiently large number of norms are collected into a developmental scale (so as to test "all the fundamental mental traits") the practical clinicist will have at his command an instrument for measuring human capacity which may lay claim to accuracy and practicability, and which can be administered without the aid of complicated mathematical formulas or the need of extended mathematical calculations. Such mechanical scales will come as near to automatically *diagnosing* cases for an examiner who through preference or need would base mental diagnoses largely on tests, as any mechanical devises ever will.[4] Certainly less diagnostic errors would be made by the judicious clinical use of such a scale than by simply computing the per cent of efficiency shown by a given subject in a few tests compared with the efficiency shown by a group of normal children of various ages in the same tests,[5] when the tests are given as group tests.

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[4] The employment for purposes of practical diagnosis of the "intelligence quotient," the absolute years of retardation and the XII-year standard of feeblemindedness is discussed in *Problems of Subnormality*.

Since the above was written Yerkes[6] has worked out a very suggestive point scale of 20 tests and has clearly pointed out some of its advantages over the Binet-Simon plan of grading. One of the chief advantages of this scale is that it permits of the granting of partial or graduated credits for partial answers. The use of partial credits has been authorized in connection with the Binet scale, but in practice the examinees have usually been rated on the "all or none" principle. It is evident, however, that according to the graduated scheme of accrediting proposed above, an individual would be given a mental age rating for each trait according to his quantitative or qualitative efficiency in the performance in question as determined by standard age-scores, established for each chronological age or fractional unit thereof. The accumulation of many such age-scores by a legitimate system of accrediting would represent the average intelligence age or mental age of the individual.

One of the patent advantages of the Binet method is the formulation of the result in terms which can be easily comprehended by the average person, and which have considerable significance, namely in terms of mental age (or the equivalent normal chronological age). While this method also has its disadvantages, I am not certain that the disadvantages can be overcome by the point scale method of rating. It would be difficult to use the pooled sum from the accumulation of points for diagnostic purposes during the *period of mental growth* without translating them into terms of normal chronological age, or successive developmental units. Seventy-five in the point scale would mean something entirely different for a five-year old than for a ten-year old. For adults it might have approximately the same significance, due allowance being made for such factors as Dr. Yerkes has specified. Nor do I see that this difficulty would be surmounted by the use of the three scales proposed more recently by Professor Yerkes to cover successive four year periods of development from 0 to 16, for, if I am correct, the pooled sum for each scale would still have different meanings for the children of the different ages or stages of development included in each scale. A scale of intelligence for school use must aid the examiner in distinguishing between the children who should be assigned to special schools for the feeble-minded and those who should be assigned to ungraded classes for the borderline, backward or merely retarded. In order to serve this purpose the scale must supply norms for each age or stage of development from the age of school entrance to at least the adolescent years.

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[5] We may be justified in concluding that two-thirds of a given group of individuals are *subnormal* because they function only two-thirds as well as a more intelligent group of the same age. But this does not justify the further inference that these two-thirds are therefore *feeble-minded*. Group tests cannot be used for the purpose of identifying feeble-minded individuals.

[6] Yerkes, Bridges and Hardwick. A Point Scale for Measuring Mental Ability, 1915. It is interesting to note that the authors have wisely refrained from laying down arbitrary points or standards by means of which to diagnose feeble-mindedness.

It would, of course, be possible to test children of different stages or ages of development and establish a pooled norm for each stage of development, and then state the results for any child examined in terms of the per cent of the normal result for his age. In such a case we should have to determine independently (1) the exact significance of any given percentage of normal functioning, say 60%, and (2) whether 60% of normal capacity at, e. g., age four would have the same significance for diagnostic purposes as 60% capacity at age 12, 16 or 20 which I am inclined to doubt, from my experience with the intelligence quotient.

Haines has shown, however, that the point scale gives more accurate results "from nine years onward," than the Binet scale.[7]

Subnormal children (clinic cases), classified according to B.-S. Age.

The differences have been computed between the averages of the shortest scores (Sh.) for each successive B.-S. age, thus: between III and IV, IV and V, V and VI, etc. The average of all the differences between the averages of each successive B.-S.

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[7] Haines, Thomas H. Mental Examination of Juvenile Delinquents. Ohio Board of Administration, Publication No. 7, December, 1915.

age for ages III to XIII, inclusive, amounts to 3.3 sec. for the boys, 4.2 sec. for the girls, and 3.5 sec. for the combined averages of the two sexes. The average improvement from mental age to mental age is somewhat less than three times as great for the boys and over three times as great for the girls as the corresponding improvement from chronological to chronological age (whole years) for the school cases. Every ascending B.-S. age shows a gain with one exception among the girls, which is negligible, as the exception is based upon the record of only one case. The greatest amount of improvement in any one age is 16.3 sec. for the boys (between ages V and VI) and 15.6 for the girls (between ages IV and V) ,while the smallest improvement for the boys is .1 sec. (between ages XI and XII), the girls registering a loss of 3.4 sec. in age XIII. This figure also represents the girls' total loss, as compared with a total gain of 45.4 sec.

The improvement is emphatically larger in the lower B.-S. ages (III to VIII), averaging for each age 5.2 sec. for the boys, 7.8 sec. for the girls, and 5.6 sec. for both sexes, as compared with 1.5 sec. for the boys, .5 sec. for the girls and 1.4 sec. for both sexes for the upper B.-S. ages (VIII to XIII). The difference between the lower and higher B.-S. ages is about the same as the difference between the lower and higher chronological ages for the school cases.

The improvement, however, does not decrease regularly from age to age, as may be seen from the following figures which show the gain (that is, the decrease in seconds) for each successive year from III to XIII for both sexes: 1.6, 6.6, 11.8, 5.4, 3.0, 3.0, 1.8, 1.2, .7, and .3. The irregularity is similar to the irregular improvement found among the school cases.

Subnormal children (clinic cases), classified according to chronological age.

The differences between the averages for the shortest scores (Sh.) for each successive chronological age were computed in the same manner as for the B.-S. ages (p. 25). The average improvement per year, for ages 4 to 16,[8] amounts to 2 sec. for the boys, 2.9 sec. for the girls and 2.4 sec. for the two sexes. It is clear that the average improvement with each ascending chronological age, whether for the school or clinic cases, is considerably smaller than the improvement with each ascending B.-S. age. The chronological improvement for the clinic cases, however, is larger than for the school cases, so that a part of the large improvement with rising B.-S. age is probably to be ascribed to the peculiarities of the clinic group.

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[8] Ages above 17 are omitted as the data are incomplete for the girls.

As with the school cases, not every chronological age shows improvement over the preceding age. There are 3 exceptions among the boys (losses in ages 11, 15 and 16), 4 among the girls (losses in ages 6, 7, 10 and 15) and 3 among both sexes (losses in ages 11, 15 and 16).

The greatest improvement in any one age is 10.4 sec. for the boys (age 6), 28.7 sec. for the girls (age 5), while the greatest loss is 5.3 sec. for the boys (age 16) and 4.5 sec. for the girls (age 6). The greatest improvement in any one age after age 9 is 2.7 sec. for the boys (age 14), 3.8 sec. for the girls (age 16) and 2.6 sec. for both sexes (age 14).

The yearly improvement is decidedly larger in the lower chronological ages (4 to 10) than in the higher ages (10 to 16) as shown by the following amounts of improvement in seconds.

	Boys	Girls	Both Sexes
In lower ages:	4.4	4.4	4.6
In upper ages:	–.4[9]	1.6	.3

The difference is larger than the corresponding difference in the B.-S. classification, except for the girls.

That the gain does not decrease regularly from year to year, is shown by the following figures, which give in seconds the amount of improvement with each ascending age from 4 to 16 for both sexes (- indicates loss instead of gain): 7.1, 9.2, 2.5, 3.4, 5.5, .4, -.6, 1.9, 1.4, 2.6, -1.8, and -1.9.

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[9] A loss instead of gain.

General Results and Conclusions

1. Psycho-motor capacity, as measured by this test, is a function of mental maturity,[10] in that it increases with increasing chronological age. This has been shown both for the normal and the subnormal children. The degree of improvement with increasing chronological age for normal children may be seen at a glance by consulting Graphs I and II, pp. 29 and 30. (The curves in each graph are based on the fastest record in the three trials. The half-yearly norms are constructed according to the scheme given on p. 4.) There are, of course, individual exceptions, and a few exceptions even among the averages, but it is probable that the latter would not have occurred had a larger number of cases been included in each subdivision. The average amount of yearly improvement for both sexes amounted to 1.4 sec. for the normal children (school cases) and 2.7 sec. for the subnormal cases. There were, however, more exceptions among the subnormal cases, although the yearly gain was about twice as large. This may be partly due to the fewer number of subnormal cases considered and to the greater variability (as indeed we shall see later) in the capacities of the subnormal cases when chronologically classified. Nevertheless, it is unexpected to find that subnormals, who are supposed to reach their maximal level early and then remain stationary, gain relatively more than the normals with ascending chronological age. However, this relatively greater gain, as will be seen presently, is in the younger ages, so that the older subnormal children do prove to be more alike than do the younger subnormal children, relatively to the

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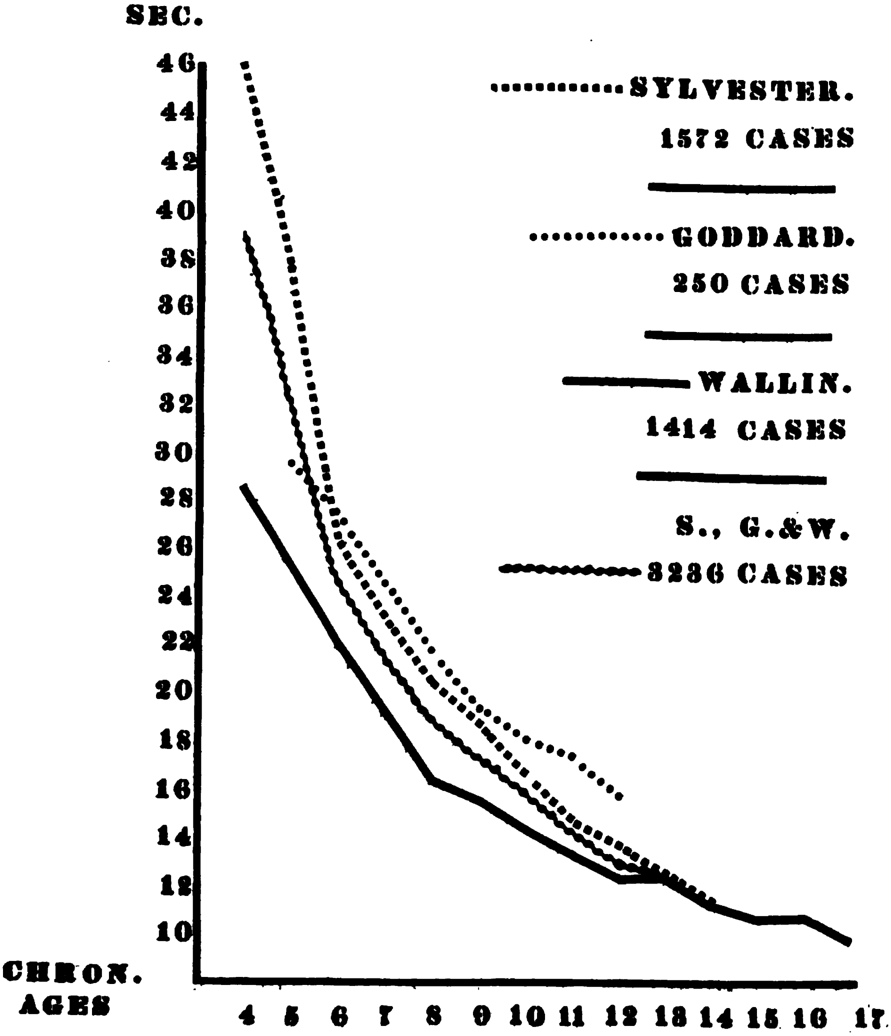
[10] I do not wish to imply that psycho-motor capacity is not also a function of physiological maturity, in this test particularly during the early years. Nor do I wish to suggest that mental and physiological maturity are unrelated variables. Both are functions of increasing chronological age, and are determined primarily perhaps by the inner growth impulse, but also to some extent by the factor of experience. The growth impulse necessarily is affected by the individual's experiences; it is furthered or hindered by these experiences. It would not be possible to conceive of the process of psychophysical maturation as being entirely independent of, or unaffected by, experience. This could only be the case where the individual failed to have any experience. Such an individual would be dead, and would suffer dissolution instead of maturation.

degree of likeness existing between older normal children as compared with younger normal children.

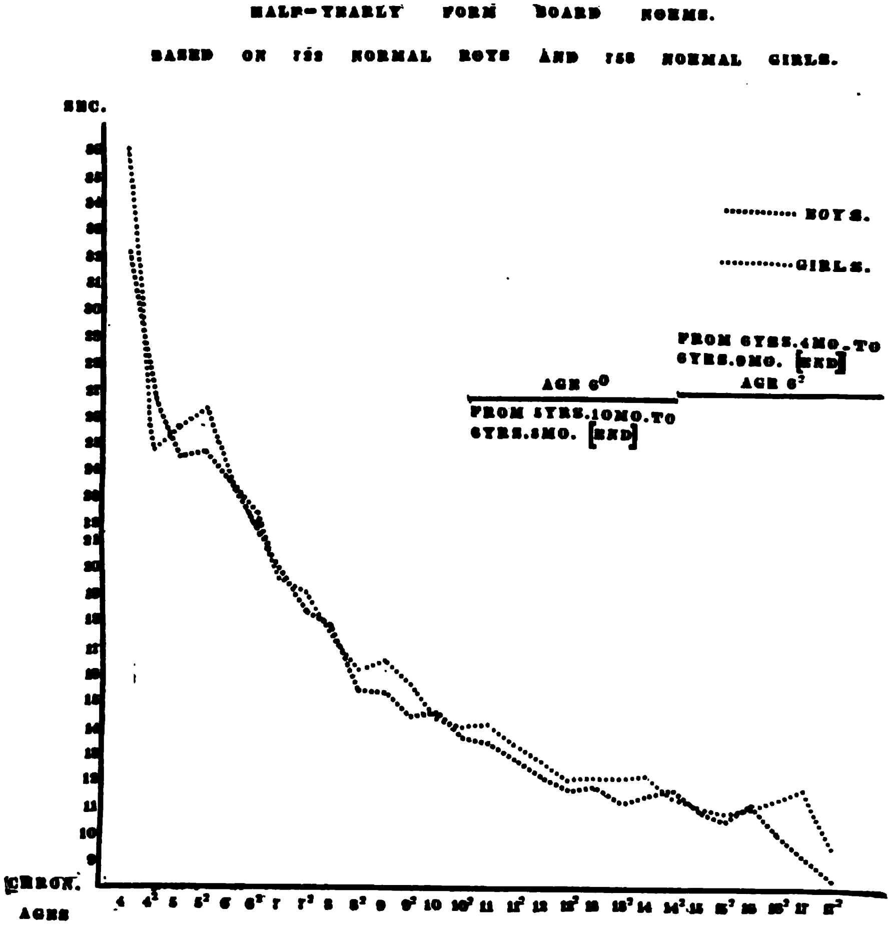
2. Psycho-motor capacity likewise increases with mental age. This has been shown for the subnormal cases. The increase,

GRAPH I.

YEARLY FORM BOARD NORMS FOR NORMAL CHILDREN



GRAPH II



amounting to an average of 3.5 sec. per B.-S. age, was much larger than the average increase for each chronological age for either the normal or the subnormal cases. It is important to determine how great the difference is between the chronological and mental ages for such a group of normal cases as we have tested, when grouped according to chronological and mental ages.

3. When normal children are classified by half-year steps, there is, again, improvement from group to group, although there are more exceptions than in the whole year classification, par-

ticularly in the upper ages. Here, too, the exceptions among the averages would probably have disappeared if a much larger number of cases had been included in each subdivision. The average half-yearly improvement for all ages, however, amounts to .70 sec., a not inconsiderate amount.

4. The improvement from age-designation to age-designation is emphatically larger for the group of younger (or lower) ages than for the group of older (or upper) ages for both the normal and the subnormal children. In other words, the difference is very much larger between successive chronological years or half-years during early childhood than during later childhood, or between successive mental ages in the lower group than in the upper group of mental ages. Based on the averages for the two sexes, the improvement in the lower half-years is more than twice as large as for the upper half-years (normal children), while the improvement for the lower whole-years is 4½ times as large as for the upper whole-years for the normal children, and about 12 times as large for the subnormal children. The average yearly improvement for the lower B.-S. ages is four times as great as for the upper B.-S. ages for the subnormal cases. See Graphs I and II.

5. The amount of improvement from year to year fails to diminish with absolute regularity either among the school cases or among the clinic cases whether classified according to chronological or mental age. However, had many hundreds or thousands of cases been included in each age-designation it is probable that the improvement would have decreased with great regularity from age to age.

Incidentally, it is worth emphasizing that our results fail to show an actual loss of capacity at age 13, although there is no gain for either the boys or the girls at this age. The curve appears to be temporarily arrested at age 13 for both sexes.

6. The results show that there is an increase in psycho-motor capacity up to the highest age tested, namely 17. The increase is not very significant in the upper ages, but this may be due to the fact that the older pupils tested were over-age for their grades and therefore presumably retarded. Actually 24% of

the pupils from 14 to 17 were reported as dull, 69% as average and only 6% as bright. That is, the per cent classified as dull is 12% in excess of the per cent so classified for all the ages, while the per cent is 6% less for both the average and the bright. Had there been a larger percentage of average and bright pupils from 14 to 17 the improvement would very probably have been larger. However, it is evident from our data that there is no experimental warrant for the statement that there is no improvement in the form-board type of psycho-motor capacity after the age of 12 (or 14), unless, indeed, we are willing to regard a gain of 2.2 sec. from 12 to 17 as insignificant (based on the Sh. scores, or 2.6 sec. based on the averages of all trials).

7. The evidence shows that psycho-motor age scales, based on form-boards such as this, should not be divided into uniform whole-age steps. Whole-year steps are too crude at the lower end of the scale and too fine at the upper end. Semi-yearly norms are feasible and necessary up to about the age of 8; from about 8 to 12 yearly norms are adequate; from 12 to 17 it seems sufficient to arrange the scores into bi-yearly norms; and beyond seventeen it may be desirable to use tri-yearly norms, but there is as yet no experimental data available to enable us definitely to settle this point.

8. The improvement with ascending age appears most clearly during the second trial, it is more apparent during the third trial than during the first, and likewise more apparent in the averages for the Sh. scores than in the first trial. Thus the average half-yearly improvement in seconds of time is about 4 times as large in the second as in the first trial, about 2½ times as large in the third as in the first, and about 2⅓ times as large for the Sh. averages as for the averages for the first trial. Since the difference between each successive step is larger in the second and third trials than in the first trial *(i. e.,* since it increases with repetition), it is apparent that, adequately to measure age differences between children, it is desirable to give the same tests more than once. The fact that the differences become larger after the first trial, would seem to indicate that pupils profit more from repetition in this test as they grow older and, by inference, as

they grow more intelligent. But in Chapters III and V we shall see that normal and intelligent pupils improve relatively less from repetition on their initial records than dull or subnormal children.

9. The improvement with increasing chronological age is greatest for the average and bright pupils and least for the dull. Based on the shortest scores in the half-year tables, the gains are over 1¾ times as frequent for the average as for the dull and somewhat less than 1⅓ times as frequent for the bright as for the dull. In seconds of time the dull pupils gain only about ⅛ as much as the average, and the bright less than one-half as much as the average. This shows that the more intelligent profit relatively more than the dull as they grow older. Dull pupils develop at a retarded pace, while the abler pupils develop at an accelerated pace.

10. The chronological age-norms for our normal children (school cases) are almost invariably higher (that is, the reaction rates are faster) than the norms furnished by other investigators. This is seen very clearly from a cursory inspection of the curves in Graph I. It is shown in detail in the tabulation on page 34 in which seven different sets of age norms are compared with our own normal chronological age standards. The figures in the D. (difference) columns represent the differences between our normal age scores and the scores in the corresponding ages in the seven other sets of norms which are tabulated. When the scores are given for B.-S. ages, they are compared with our norms in the corresponding chronological ages. The final averages at the bottom of the table are for ages 4 to 12, inclusive (except in the third set where there is no score in age 4). Other ages are not included because of lack of comparative data in all the sets.

There is only one instance in which our reaction rates are slower (in the fifth set the feeble-minded are faster by .4 sec. in age 12), and one instance in which they are equal (in the second set the normal children are equal to ours in age 14). In all the other instances our reaction rates are faster than those supplied by the other investigators. The average difference when compared with Sylvester's normal cases amounts to 5.6 sec. for ages 4 to 12 (i. e., the average of all the average differences), and 4.4 sec. when compared with Goddard's cases, tabulated according to chronological age for ages 5 to 12. The average difference is somewhat less, 4.6 sec., for Sylvester's cases when ages 13 and 14 are included in the comparison. When our results are compared with Goddard's normal cases classified according to B.-S. age[11] the average difference reaches 4 sec. There is thus a very significant difference between our norms and those of Sylvester and Goddard for normal children, to which we shall recur presently.

The average difference is considerably larger for the lower ages than for the higher ages. For ages 4 to 7 it amounts to 9.5 sec. compared with Sylvester's cases and 5.4 compared with Goddard's cases classified according to B.-S. age; and for ages

Differences between the author's form-board norms for normal children and the norms supplied by other investigators or by other types of subjects.

	1	2	3	4		
	Wallin's norms used as standards of comparison, based on normal chron. age	Sylvester's normal cases ar. ac. to chron. age[1]	Goddard's normal cases ar. ac. to chron. age[1]	Goddard's normal cases, ar. ac. to B.-S age[2]		
Age	Age scores	D.	D.	No.	Age scores	D.
2						
3						
4	28.4	17.6		7	33.8	5.4
5	25.4	12.2	4.1	7	30.3	4.9
6	22.1	4.4	5.4	13	27.5	5.4
7	19.3	4.0	5.2	47	25.4	6.1
Ave. 4-7		9.5				5.4
8	16.5	4.1	5.3 5.0[6]	43	20.7	4.2
9	15.6	3.0	3.7	46	19.2	3.6
10	14.4	2.3	3.8	69	16.6	2.2
11	13.4	1.5	4.2	25	15.9	2.5
12	12.4	1.4	3.5	14	14.3	1.9
Ave. 9-12		2.0	3.8			2.5
13	12.5	.1				
14	11.6	.0				
15	11.4					
16	10.9					
17	10.2					
Ave. 4-12		5.6	4.4[7]			4.0
Total No.				271		

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[11] It should be explained that Goddard classifies his cases according to "mental age," but he does not state whether his mental ages were determined by the B.-S. tests, and if so whether by the 1908 or 1911 revisions. I assume that his mental ages were determined by the B.-S. scale.

	5 Goddard's f.m. cases, ar. ac. to B.-S. age[2]		6 Wallin's sub-normal (mostly f.m.) cases, ar. ac. to chron. age[3]		7 Wallin's sub-normal (mostly cases, ar. ac. to B.-S. age[4]		8 Wallin's Epileptics, f.m.) ar. ac. to B.-S. age[5]		
No.	Age scores	D.	Age scores	D.	Age scores	D.	No.	Age scores	D.
							6	84.1	
			50.0		49.1		8	227.0	
53	76.1	47.7	49.1	20.7	47.5	18.1	12	110.6	82.2
52	51.2	25.8	42.0	16.6	40.9	15.5	8	84.0	58.6
54	38.2	16.1	32.8	10.7	29.1	7.0	22	63.6	41.5
85	26.3	7.0	30.3	21.0	23.7	4.4	32	32.5	13.2
		24.1		17.2		11.5			48.8
87	23.8	7.3	26.9	10.4	20.7	4.2	54	25.5	9.0
48	18.3	2.7	21.4	5.8	17.7	2.1	28	20.9	5.3
29	17.5	3.1	21.0	6.6	15.9	1.5	82	18.9	4.5
8	16.4	3.0	21.6	8.2	14.7	1.3	27	16.1	2.7
4	12.0	−.4	19.7	7.3	14.0	1.6	11	15.0	2.6
		2.1		6.9		1.6			3.7
			18.3	5.8	13.7	1.2	18	14.4	1.9
			15.7	4.1					
			17.5	6.1					
			19.4	8.5					
			17.4	7.2					
		12.4		11.9		5.7			22.1
420							308		

F.-m., feeble-minded. Chron., Chronological. D., difference between the standard scores in set 1 and the scores for corresponding ages in the other sets. The reaction rates are slower in the comparative sets than in the standard set in all cases except age 12, set 5. Ar., arranged. Ac., according. Ave. 4-12, average of all the differences in ages 4 to 12, inclusive. Ave. 4-7, same for ages 4-7. Ave. 9-12, same for ages 9-12. Total No., total number of cases.

[1] The age-norms for these sets are given in Table XLIX.

[2] Goddard, as before.

[3] The age-norms used are the averages of the shortest scores for both sexes given in Tables XXVIII to XLVII.

[4] The age-norms are the averages of the shortest scores for both sexes in Tables XVI to XXVII.

[5] Experimental Studies of Mental Defectives, p. 74. Detailed data for the two sexes and for children and adults are available in the original table.

[6] Average of ages 5 to 8.

[7] Average of ages 5 to 12.

9 to 12 the corresponding figures are, 2. sec. compared with Sylvester's cases and 2.5 sec. compared with Goddard's cases. For ages 5 to 8 for Goddard's cases classified chronologically it amounts to 5 sec., and for ages 9 to 12, 3.8 sec.

From the general results it would seem that Sylvester's norms are lower (*i. e.*, slower) than Goddard's (chronological classification), but an examination of the table shows that Sylvester's rates are faster in all ages except age 5. Goddard's cases, however, are so few as to render this exception negligible. Of the three investigators Goddard gives the lowest (easiest) age-standards.

Feeble-minded children when classified according to B.-S. age react more slowly than normal children of corresponding chronological age. Goddard's feeble-minded cases average 12.4 sec. slower per age, while my clinic cases average only 6.3 sec. slower when classified according to B.-S. age. When classified according to chronological age the average difference of my cases reaches 11.9 sec. For ages 4 to 17 the difference amounts to 9.9 sec. It is, again, apparent that my cases do considerably better than Goddard's, differing only about half as much as do his from my normal cases. It is to be remembered, however, that only 39.64% of my clinic cases were classified as feeble-minded, or border-line (all the rest except 14% being backward or retarded), while it is to be presumed that all of Goddard's cases were feeble-minded.

Goddard's feeble-minded cases were slower than his normal cases (chronological classification) in the four lower ages (5 to 8), but faster in the 4 higher ages (9 to 12).[12] In ages 11 and 12, however, his feeble-minded cases are so few as to render any conclusions hypothetical. However, the differences between the age-norms for our normal cases and for Goddard's and our own feeble-minded cases is also very much larger in the lower (4 to 7) than the higher ages (9 to 12). For the lower ages it amounts to 24.1 sec. when compared with Goddard's, and 11.5 sec. when compared with our feeble-minded cases (B.-S. classification). For the upper ages the corresponding differences are 2.1 sec. and 1.6 sec. The difference for the lower ages for our feeble-minded cases classified chronologically amounts to 17.2 sec., and for the upper ages 6.9 sec.

The reason why the feeble-minded, when compared with normal children, do relatively better in the higher mental ages is due to the fact that the average chronological age is higher for children in the upper mental ages than in the lower mental ages, and there is some correlation between intelligence and chronological age even in the feeble-minded. Many of the children in the upper B.-S. ages were many years older than the normal children in the corresponding chronological ages.

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[12] The relative superiority of the feeble-minded in the upper B.-S. ages, as shown elsewhere (p. 82), is due to increasing chronological age.

The slowest records invariably are made by the epileptics. They react on the average 24.4 sec. slower than our normal cases. If age 13 is included the average difference is reduced to 22.1 sec. Here, again, and for the same reason, the difference is emphatically larger for the four lower ages (48.8 sec., ages 4 to 7) than for the four higher ages (3.7 sec., ages 9 to 12). Our epileptics react slower than Goddard's feeble-minded in all ages except 11 (but Goddard's average in age 11 is based on only 8 cases), and slower than our feeble-minded cases in all ages. The average difference for ages 4 to 9 between the epileptics and Goddard's feeble-minded cases amounts to 11.9 sec., and for our feeble-minded (B.-S. classification), 18. sec. For the lower 4 ages (4 to 7, inclusive) the average difference between the epileptics and Goddard's feeble-minded is 24.7 sec., and between the epileptics and our feeble-minded, 37.3 sec., while the corresponding differences for the higher 4 ages (9 to 12) are 1.7 sec. and 2.1 sec. When compared with my feeble-minded cases classified chronologically the epileptics are inferior in all the lower ages (3 to 7), but superior in all the upper ages (8 to 13). This is due to the fact that the intelligence of our feeble-minded cases does not increase markedly in the higher chronological ages, owing to the fact that some of the older cases were imbeciles and low grade morons.

From the data shown above it is obvious that entirely discrepant results in the psycho-motor rating of clinic cases would be secured according as the examiner made use of Sylvester's, Goddard's or my own age-norms. I recall very distinctly that when I was using Goddard's norms the psycho-motor age of my clinic cases in the majority of instances was distinctly higher than their B.-S. age, so much so that I had been led to believe that motor development as a rule was distinctly in advance of intellectual development. On the other hand, when I used Sylvester's norms the superiority of motor over intellectual age was not nearly so pronounced.

In order to show the significance of these statements I have computed the psycho-motor ages by means of Sylvester's, Goddard's and my own normal chronological norms for the last 100 consecutive cases in my clinic files. In order to obtain a hundred records, however, it was necessary to examine 125 cases. Twenty-five records had to be discarded, either because the rates were so slow that they could not be brought within the lower limit of Goddard's and my own scale or within the upper limit of Goddard's norms. When the age-norms supplied by these 3 investigations did not precisely correspond with the individual reaction rates (fastest record out of three) of my clinic cases, the age-norms were estimated in tenths of a second and interpolated between the available norms. Thus the score 17 sec., which falls between ages 7 and 8 in my scale, was estimated as age 7.8 years.

The average psycho-motor age in each column was determined by averaging the ratings according to the standards of the different investigators for all the subjects in a given B.-S. age classification. All of the subjects had been given the B.-S. tests according to my own 1908 Guide. The subjects have also been rated by the 1911 scale, but the 1911 rating is not used here. We shall compare the 1908 and 1911 ratings elsewhere.

From the table on page 39, it is apparent that the average psycho-motor age which the children attain is higher in every age when measured by Sylvester's and Goddard's norms than when measured by my own, and that it is higher when measured by Goddard's than by Sylvester's age standards in all except the two lowest ages. The average difference between Sylvester's and my rating is 1.7 years, and between Goddard's and my own, 2.22 years. This represents the average of all the differences for all the 7 ages considered. The largest difference in any one age between Sylvester's and my standards is 2.0 years, Age VIII; and between Goddard's and my standards 3.2 years, age X. The smallest difference in any one age is 1.5 years (Sylvester, age VI; Goddard, age IV). The smallest difference in any one age between Goddard's and Sylvester's norms is .1 and the largest 1.5 years.

It requires little argument to convince any one that when the difference in psycho-motor rating by Sylvester's and Goddard's norms may amount to 1.5 years, and when 1.5 years is the smallest difference in any age between the rating according to Goddard's or Sylvester's and my own norms, wholly discrepant clinical conclusions will be drawn with respect to the psycho-motor capacity of the individual pupil according to the standard of measurement which is employed.

Psycho-motor age as determined by Sylvester's, Goddard's and Wallin's Norms and the combined averages of the results of these three investigators.

No.	Sylvester	Goddard	Wallin	S., G. & W.
1	5.8	B.-S. Age IV 5.5	4.0	5.5
2	6.1	B.-S. Age V 6.0	4.5	5.6
10	6.9	B.-S. Age VI 7.1	5.4	6.3
24	7.6	B.-S. Age VII 8.0	6.0	7.0
38	8.4	B.-S. Age VIII 9.2	6.4	7.9
13	9.4	B.-S. Age IX 10.6	7.7	9.2
12	9.6	B.-S. Age X 11.1	7.9	9.4

No., number of cases. Figures represent averages. S., G. & W., psycho-motor age as determined by the averages based on all of Sylvester's, Goddard's and Wallin's normal cases.

What is the explanation of these large discrepancies? The results of each investigator seem to be consistent within themselves, in that the age-norms consistently show an increase with increasing age. There are four explanations which suggest themselves.

First, the methods of giving the test may have differed. Goddard told the child to "put each block into its hole as fast as he can." He does not indicate whether the child was especially urged to do his best in all three of the trials. Sylvester did not specially urge the child during the first trial to do his best ("uninstructed first trial"), but he did urge him to "make the best possible record" during the second and third trials. On the other hand, my cases were uniformly urged to do their best from the very first. This factor may be of importance, since both Sylvester's and my results show that the majority of children improve from test to test. Since my cases were incited to put forth their best efforts from the beginning, it is probable that their "best" records would be relatively somewhat better than

Sylvester's "best" records, which are based on the shortest record in the last two trials instead of the shortest record in all three trials.

Goddard showed the child what was "to be done by placing a few blocks in their proper hole," while Sylvester after the first trial gave the child "any instructions necessary to make him understand where the blocks belong." The latter statement is too vague to enable us to determine the precise nature of the assistance rendered, but it does not appear that Sylvester actually placed any blocks in their recesses, although he handed blocks to children of four years or less. None of my cases (except a few babies) saw the blocks placed in the recesses, but they saw them rapidly removed by the experimenter at the beginning of the test. Goddard's cases evidently received the greatest aid, but they fail to show it in the results.

As far as it is possible to judge from the available description, Goddard started the stop watch when the signal to start was given and stopped it when the last block was in place. Sylvester used a "ready-go" signal, but he does not make clear precisely when the watch was started or when it was stopped. My timing, as explained on p. 13, invariably began when the child's hand touched the first block, and closed when the last block was down in the recess. The method of timing may be a factor, but this cannot be definitely determined because the statements in the texts are not sufficiently detailed. If Goddard and Sylvester started the watch before the child's hand touched the first block their reaction rates would necessarily be somewhat slower.

The blocks were placed in a pile at the right of the board (child's right) in Goddard's and my own work. Sylvester placed them in three piles along the side of the board farthest removed from the child. This is probably an unimportant factor, although satisfactory experimental data are lacking.

The second factor concerns the personnel of the examiners. Sylvester evidently gave all of his tests himself, thus insuring uniformity of administrative conditions (although not necessarily, because the same experimenter may vary from his conditions as a result of fatigue, exhaustion, freshness, etc.). My tests were given by myself and two assistants who had observed me test numerous cases and who were trained to bring out the best responses of the children from the outset. I cannot, however, state from personal observation whether or to what extent my assistants varied from the prescribed conditions. Goddard does not state who gave the tests to his normal cases. This factor may have been partly responsible for the discrepancies, but the published data are too incomplete to permit of more than a conjecture, nor is there any experimental evidence available which demonstrates the dependence of the results on the personal equation of the examiner. We have, however, frequently noticed large differences in the ability of different students to get results in this test in our clinic courses.

The third factor relates to possible environmental (geographical) differences which would promote or retard motor development. Thus city children as the result of environmental conditions probably develop the habit of rapid reaction. Again, the energy of the Pittsburgher in constructive achievement in the material arts is notorious. Sylvester's cases came from Philadelphia, most of my cases came from Pittsburgh, while Goddard does not state where he got his cases. They probably came from the country or the country village. However, no data are at hand by which to evaluate this factor.

The fourth factor concerns the distribution of the grade of intelligence of the cases tested. Goddard merely makes this statement regarding the character of his array of "normal" cases: "The slight deviations in the time (between his chronological and mental ages) shows the presence of some children who are slow, backward or feeble-minded." In case he utilized an unselected array of children from the school cases which were tested by the Binet-Simon scale, it is probable that a large percentage were more or less mentally deficient, because according to his Binet testing 8.4% of those cases were retarded from 3 to 7 years. Sylvester excluded all "especially backward or peculiar children." So far as it is possible to judge, my array (see p. 9) probably included a smaller percentage of backward and a larger percentage of bright children, than either Goddard's or Sylvester's.

The probability, therefore, is that my norms are higher (*i. e.*, the rates are shorter) both because my cases as a group graded somewhat higher in intelligence and because they were incited to do their very best in each trial. Which of these two factors is the more important cannot be determined from the available published data.

Accepting the revelancy of the first factor (we have elsewhere demonstrated the superiority of the abler pupils in this test, Chapter III) we have here an indication of the correctness of the position which has been previously taken, namely that norms for normal children must be based on selected cases of normal mentality, and not on an unselected array of school cases, one-third of whom are usually behind grade although, to be sure, not because of mental deficiency. We would suggest as a satisfactory distribution of cases the following: 75% of average or normal mentality; and 12.5% of retarded and backward, and 12.5% of bright and able pupils.

Because of the significant differences revealed by the foregoing analysis, I have combined Goddard's, Sylvester's and my own results into a common scale (in the final column of Table XLIX). The combined values, of course, lie between Goddard's low standards and my own high standards. The average differences for ages IV to X (see page 39) between these combined norms and Sylvester's, Goddard's and my norms is + .48, + .94 and — 1.28 of a year, respectively. That is, the cases would rank higher by Goddard's and Sylvester's norms and lower by my norms, by the amounts indicated.

The reprinting of the norms of other investigators in this book (p. 34f. and Table XLIX), makes it possible for the clinical worker to use whatever set of norms he may prefer. In case my norms are used, care must be taken to conform strictly to the conditions laid down. In urging children to put forth their best efforts, the examiner must use great tact, otherwise the children may become excited and actually do worse than if they were left free to set their own pace. Examiners who do not care to grade children by the half-yearly norms, will probably prefer to use the combined Sylvester-Goddard-Wallin norms which they may regard as most reliable or conservative, since they represent the mean results of three independent investigations, although, as must be recognized, the methods employed by the three investigators have not been exactly the same.

CHAPTER III

PSYCHO-MOTOR CAPACITY IN RELATION TO GRADE OF INTELLIGENCE

School cases, or normal children

Comparison of dull, average and bright pupils

We shall first compare the differences between each of the three successive ascending groups of ability: that is, between the dull and the average, and between the average and bright, for all the ages and for all the trials (I to Sh.), limiting the comparison to the combined averages for the two sexes in the whole-year classification, in Tables I to XV. This makes it possible to consider 104 losses or gains between the three grades of pupils (dull, average and bright).

In 62% of these comparisons (65 instances) the abler pupils do better than the less able; *i. e.*, the average do better than the dull and the bright do better than the average pupils in the same age; in 36% of the instances compared (38 cases), the abler pupils do not do as well; and in 1% (1 instance) the scores are the same. The gross amount by which the abler surpass the less able pupils for all ages and all trials (I to Sh.) is 154.6 sec., while the gross amount by which the less able do better than the abler is 41.5 sec. Thus the total amount by which the more intelligent surpass the less intelligent is 113.1 sec., which is an average superiority of 1.08 sec. for each instance compared or, in other words, for each age.

The per cents of instances in which the abler pupils do better than the less able are for each successive trial as follows: I, 65% (equal in 4%); II, 65%; III, 53%; and Sh., 65%. The more intelligent surpass the less intelligent less frequently, during the third trial.

The average amount in seconds per year by which the abler pupils surpass the less able is as follows for each trial: I, 1.5 sec.; II, 1.2 sec.; III, .85 sec.; and Sh., .65 sec. On the whole, the abler pupils show their superiority most in the first two trials.

Separate comparison of average and dull pupils

The average pupils surpass the dull in 81% of the comparisons (52 instances), while the dull surpass the average in 19% of the cases (10 instances). The total amount by which the average surpass the dull pupils for all ages (5 to 17) and all trials (I to Sh.) is 115.2 sec., while the corresponding total amount by which the dull do better is 9.2 sec. Subtracting the latter from the former figure and dividing by the number of comparisons gives the average superiority of the average pupils per age, which is 2.0 sec.

The average pupils surpass the dull least frequently in the first trial (in 69% of all the comparisons, as compared with 84% in II, III and Sh.). The average superiority per year in units of time is also less in the first trial (1.8 sec.) than in the second (2.5 sec.), or third (2.1 sec.). It is least, however, for the shortest scores (1.5 sec.).

The younger average pupils (ages 5 to 10, inclusive) surpass the younger dull pupils more frequently (in 91% of all comparisons) than the older average pupils (ages 12 to 17) surpass the older dull pupils (66%). The average amount of superiority per year over the dull pupils is also very much larger among the younger than the older average pupils (3.6 sec. vs. .41 sec.).

Comparison of average and bright pupils

There is very little difference between the average and bright pupils. The average pupils surpass the bright rather more frequently. They are ahead in 52% (or 27) of all the comparisons, the bright are ahead in 46% (or 24), while in 2% (or 1) the scores are equal. In units of time, however, the bright are slightly ahead. The total amount by which they excel the average for all ages and for all trials (I to Sh.) is 39.4 sec., while the corresponding total for the instances in which the average excel is 32.3 sec., a gross difference of 7.1 sec., or an average difference per year of .14 sec., which is quite negligible.

In the younger years (ages 4 to 9, inclusive), the bright pupils excel in only 46% of the instances compared (11), the average in 50% (12), and the scores are equal in 4% (1). But here, again, the bright surpass the average to a slight extent in the amount of superiority—by an average of .4 sec. per year.

In the older years (ages 11 to 16, inclusive) the average pupils are consistently ahead, excelling in 54% of the comparisons (13 out of 24), with an average superiority per year of .3 sec.

When the data are analyzed separately for each trial it is seen that the bright do consistently better than the average in the first trial, and consistently poorer in the other trials. In the first trial the bright excel in 61% of the ages (8 ages), the average in 31% (4 ages), and the scores are equal in 8% (1 age). The average amount of superiority per year amounts to 1.2 sec. In the remaining trials the average surpass the bright by the per cent of ages (first line) and by the average amount in seconds per year (second line) which are indicated in the following tabulation:

	II	III	Sh.
Per cent of ages:	54	67	54
Amount of superiority:	.06	.38	.24

It is evident that so far as there is any significant difference, it is limited to the first trial.

Comparison of dull and bright pupils.

The relation between form-board performance and intelligence should be best seen by comparing the extreme groups, the dull and the bright children. The bright children surpass the dull in 81% of the comparisons (39 instances), while the dull excel the bright in 19% (9 instances). The sum of all the cases in which the bright excel amounts to 124.9 sec., while the sum of all the instances in which the dull excel amounts to 12.8 sec. Deducting the latter figure from the former, and dividing by the number of comparisons (48), we get 2.3 sec. as the average amount per year by which the bright surpass the dull.

The bright pupils surpass the dull most frequently in the first trial, and the average amount of superiority is likewise largest in the first trial, as indicated by the following per cent of instances and the amounts in seconds by which the bright excel the dull:

Trial:	I	II	III	Sh.
Per cent of instances in which bright excel:	91%	75%	75%	83%
Amount of superiority of bright over dull:	3.4 sec.	2.1 sec.	2.2 sec.	1.5 sec.

Although the older bright children (ages 11 to 16, inclusive) excel the older dull pupils almost as frequently as the younger bright children (ages 5 to 10, inclusive) excel the younger dull ones, the average amount of superiority in seconds of time per year is very much greater for the young bright compared with the young dull (4.0 sec.), than the corresponding figure for the older bright compared with the older dull pupils (.58 sec.). There may be several reasons why the older bright children do relatively poorer than the younger bright. First, the dull pupils catch up more and more as they grow older. This may be so (and undoubtedly is so in individual cases) but evidence has been found indicating that these retarded pupils continued to develop at a retarded pace all along (pp. 18f., 33). Second, the pupils who were over fourteen were all more or less over-age for the elementary schools. Hence they were all pedagogically retarded. The teachers probably rated them as bright, average and dull relatively to one another and not relatively to children of the same age who were up to grade. Teachers and parents constantly tend to rate children relatively to those in the same class, or those with whom they associate, although the other children may be younger. Thus both the parent and the teacher reported recently that a subnormal child was doing just as well as his classmates and therefore he could not be subnormal. Examination, however, revealed that the child was 8 years old while his classmates averaged about 6 years. Consequently, since our children over 14 were pedagogically retarded and more or less mentally retarded, they were more alike than would have been the case with a similar number of children taken from a normal distribution of intelligence. Third, only a few cases were available for comparison, particularly so far as concerns the pupils classified as "bright." Ages 14 to 16, inclusive, contain only 9 bright as compared with 33 dull pupils.

Clinic cases, arranged according to B.-S. age

In studying the intelligence factor in the clinic group we shall first compute the losses or gains between each successive ascending group of intelligence within each B.-S. age[1] which is available for comparison in Tables XVI to XXVII. That is, we shall compare the imbeciles with the morons (or the next higher group if morons are lacking), the morons with the border-line cases (or the next higher group available), the border-line with the backward, the backward with the retarded, etc., in the *same* B.-S. age. The comparison will be based on the shortest scores (Sh.) only, considered separately for the boys and girls (37 comparisons for boys and 30 for girls). That is, the boys' averages in a given classification will be compared with the boys' averages in the next higher classification; and the girls' averages will similarly be compared with the averages for girls and not for boys in the next higher classification.

In 53% of the cases, irrespective of sex, there is an improvement, and in 46% a loss of efficiency, from group to group. The corresponding per cents for the boys are 54% (gain) and 46% (loss), and for the girls 53% (gain) and 46% (loss).

The total amount of improvement from group to group for the 36 comparisons in which improvement is shown is 147.2 sec., while the total loss for the 31 cases showing losses is 142.2 sec. The average amount of gain from group to group (that is, the difference between the total gain and the total loss divided by the number of comparisons) is thus only .074 sec., which is entirely negligible. The corresponding gain for the boys is .032 sec. (91.2 — 90.0 ÷ 37) and for the girls, .12 sec. (56.0 — 52.2 ÷ 30).

We may, in the second place, compare the scores (Sh. only) between the lowest and the highest groups of intelligence for the boys and girls separately which are available for comparison in each B.-S. (17 instances). The data, unfortunately, do not permit of comparison in all ages between the extreme groups, *e. g.*, between the imbeciles and bright children, as may be seen in detail by an examination of the tables. In only 59% of the instances compared for both sexes combined do the highest groups show improvement over the lowest groups; in 35% they show a loss, while in 5% the averages are equal.

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[1] The difference between each *successive* B.-S. age also represents an intelligence difference, but this is considered in Chapter II.

The boys' averages show a gain in 50% and a loss in 50% of the cases; while the girls' averages show a gain in 71% and a loss in 14% of the cases, while the averages are equal in 14%.

The gross amount of gain for all B.-S. ages is 33.1 sec., while the gross amount of loss is 61.3 sec., leaving an average loss per B.-S. age of 1.6 sec. If, however, two instances of abnormally large losses are eliminated (boys 31.4 sec. and girls 18.4 sec.), the average gain per year, irrespective of sex, is only 1.4 sec. The corresponding figure for the girls is 3.1 sec., and for the boys .35 sec.

In view of the positive correlation found in general between form-board efficiency and the degree of intelligence among our normal cases when compared with children of the same chronological ages, why is a similar correlation not more pronouncedly evident, instead of almost lacking, when comparison is made between the more extreme and numerous groups of our clinic cases when classified according to mental age? Even the average improvement between the lowest and the highest grades in the same mental ages amounts to less than one and a half seconds. Either our conclusion from the analysis of the school data is fallacious, or the grouping of the clinic cases is wrong, or the comparison is vitiated because the clinic cases are classified according to B.-S. age instead of according to chronological age. That the latter is the true explanation would appear from theoretical considerations. In the B.-S. classification children of markedly different chronological ages are averaged together in each B.-S. age. As a consequence the children in a low group may readily equal or excel the children in a high group, because the children in the low group may be considerably older chronologically. It is not to be expected, for example, that normal or bright B.-S. VI-year children of a chronological age of five years will do better than B.-S. VI-year imbeciles of a chronological age of, say, 9 or 10 years. The latter might conceivably do considerably better than the five-year old bright children although the mental level of the two groups was about the same. I have found that more 3- and 4-year old normal children fail to do this form-board test than defectives with a mentality of only III or IV years. The ability measured by this test increases not only with mental age, but also with chronological age. That the factor of chronological age is, in fact, responsible for the discrepancy appears from a consideration of two sets of facts.

First, not only does the chronological age fail to increase regularly or significantly, but it actually decreases, with each ascending group of intelligence within each B.-S. age. This is shown in the tabulation on p. 67 where the average chronological ages are given for the boys and girls separately for all the groups of intelligence from imbeciles to bright cases, irrespective of B.-S. rating. It is seen that the chronological age decreases with each higher group of intelligence with only one exception each for the boys and girls.

The following tabulation shows the same fact for one of the B.-S. ages (VII) which contains all of the intelligence groups except idiots. The figures represent the average chronological age in each group.

Groups:	Imbeciles	Morons	Border-line	Backward	Retarded	Normal	Bright
Boys:	13.33	12.18	9.38	8.79	8.17	7.59	5.45
Girls:	13.70	11.86	9.86	9.41	7.58	6.87	6.08

Not only does the chronological age not increase regularly from age to age, but the exact opposite occurs: the chronological age decreases regularly for both the boys and the girls in each ascending group of intelligence. That the bright children were not markedly superior to the imbeciles in this age is not surprising when it is seen that the latter are more than twice as old as the former.

Second, when the clinic cases are classified according to chronological age a very marked improvement does, as a matter of fact, occur with increasing grade of intelligence. This will be shown in the following analysis.

Clinic cases, arranged according to chronological age

The intelligence groups are arranged and compared precisely as in the B.-S. classification of the clinic cases (see Tables XXVIII to XLVII). That is, the average of the lowest group in any chronological age (say, the averages of the imbeciles) is compared with the average of the next higher group (say, morons) in the same chronological age, and the amount of gain or loss is calculated. Only the averages based on the shortest scores are compared (55 comparisons for the boys and 39 for the girls). Comparisons are occasionally impossible in the lowest and highest chronological ages because of the absence of data in the different classifications. Likewise comparisons between the lowest and highest classifications in each age are sometimes restricted to adjacent or nearly adjacent classifications, because of the absence of the extreme classifications. Reference to Tables XXVIII and XLVII will indicate in detail all the comparisons which could be made.

In 80% of the comparisons, irrespective of sex, there is an improvement, and in 17% a loss of efficiency, from group to group, while in 2% the averages are equal. The corresponding per cents for the boys are 87% (gains), 10.9% (losses) and 1.8% (equal), and for the girls 71% (gains), 25% and 2.5%.

The total amount of improvement for the 76 instances showing gains is 555.8 sec., while the total amount of loss for the 16 instances showing losses is 79.1 sec., leaving a net gain of 476.7 sec. The average amount of gain from group to group for all the 94 comparisons (including two instances of equal scores) thus amounts to the considerable sum of 5 sec., instead of the negligible amount found when the groups were compared in the B.-S. classification. The corresponding gains for the boys is 5.5 (356.7 — 54.4 ÷ 55), and for the girls, 4.4 sec. (199.1 — 24.7 ÷ 39).

When we compare, as before (p. 47), the averages in the lowest and the highest groups of intelligence which are available in each chronological age, it is found that there is a gain in 88% of the 25 comparisons for both sexes, a loss in 8%, and the same results in 4%. The corresponding per cents for the boys are 86% (of gains), 7% (losses) and 7% (equal), and for the girls 91% (gains) and 9% (losses).

The gross amount of gain for the 23 instances of gain in all the chronological ages is 504.5 sec., and the gross amount of loss (2 instances) is 1.7, leaving an average gain from the lowest to the highest group in each chronological age of 20.1 sec. The corresponding figure for the girls is 17.8 sec. and for the boys 21.8 sec. It is apparent that there is an enormous increase in form-board efficiency with increasing intelligence when the subnormal cases are classified according to chronological age.

General Results and Conclusions

1. Psycho-motor efficiency, as measured by this test, varies with the grade of intelligence. This has been shown both for normal and abnormal cases. Average children do better than dull children of the same age, bright better than average (although not clearly so indicated for our school cases), backward better than feeble-minded, morons better than imbeciles. We have already emphasized the corroborating fact that the speed is found to vary with ascending chronological age for normal children and with ascending B.-S. age for subnormal cases (pp. 28 and 29).

2. The fact that our average school children surpassed the dull children more consistently and more pronouncedly (in 81% of the comparisons and by an average of 2 sec. each age) than the bright children surpassed the average children (in only 46% of the comparisons but by an average of only .14 sec. per age) would seem to indicate either that some of the average cases should have been classified as bright, or some of the bright cases should have been classified as average. As a matter of fact one of the schools did not rate any of the children as bright, although it is quite probable that some should have been so rated, while two schools classified as many as 16% of the children enrolled at the time as among the "brighter" pupils. It is quite probable that had these schools been asked to classify all their pupils into three groups of dull, average and bright, many of the "brighter" cases would have been classified as "average," and the "brighter" children would then have clearly surpassed the average. Moreover, it is also probable that many of the children included among the "brighter" pupils in the school in the poorer section would not have been so rated in the school located in the socially and financially superior district. These considerations suggest that

the grouping of the bright pupils is less accurate than the grouping of the average or the dull pupils, hence the smaller difference between the bright and the average than between the average and the dull.

3. When different grades of subnormal, normal and supernormal children are sub-classified into intelligence groups in the mental age (B.-S.) in which they belong, there is little, if any, increase in efficiency with each ascending group of intelligence (within the same mental age). There was improvement only in 53% of the groups compared, with an average gain per group of only .074 sec. The reason there is practically no improvement is that when children of the same mental age are classified into groups according to degree of brightness (or dullness) the chronological age usually decreases instead of increases with each ascending intelligence group. Hence the increasing skill which we have found to be correlated with intelligence is neutralized by the higher chronological ages in the less intelligent groups. On the other hand, when the pupils are similarly arranged in subgroups within the same chronological age, there is a decided increase in capacity with each ascending group of intelligence. It is found that 80% of the successive groups compared show an increase, while the average increase per group amounts to 5 sec. The average increase between the lowest and the highest group of intelligence is 4 times as large. The reason for the improvement here is that the heightened psycho-motor capacity which goes with intelligence is not affected by chronological age, since the chronological age is constant. It is clear that psycho-motor capacity varies not only with mental age but also with chronological age. Thus a 13-year old imbecile with a VII-year mentality may be superior to a 5-year old bright child of the same mental age.

4. It is, therefore, evident that wholly erroneous conclusions may be drawn with respect to the differences in various mental traits between various intelligence grades of children or adults when the subgroups are arranged according to mental age instead of chronological age. No matter how important and desirable it may be to regard the mental classification as basic, no

analysis is adequate unless the data have also been classified according to chronological age. Hitherto such a two fold analysis of psychological data has never been attempted on an adequate scale.

5. The younger among able pupils apparently do relatively better than the older abler pupils compared with the younger and older among less able pupils. Thus the young average pupils surpass the young dull pupils in 91% of the comparisons and by an average of 3.6 sec., while the older average pupils surpass the older dull pupils in only 66% of the comparisons and by an average of only .41 sec. Likewise the young bright surpass the young dull pupils by a larger average amount than the old bright surpass the old dull (by 4 sec. compared with .58 sec.), but the frequency is about the same. The comparison between average and bright pupils gives ambiguous results.

6. The abler or more intelligent pupils show their superiority over the less intelligent pupils more frequently or more decidedly in the first or second trial than in the third trial. The bright pupils excel the average consistently in the first trial, while the average are ahead in the other trials. Likewise the bright surpass the dull pupils most frequently and most emphatically in the first trial. The average pupils, however, surpass the dull more frequently and by larger average amounts in the second and third than in the first trial. On the whole, these results probably justify the conclusion reached elsewhere (pp. 77f, 80, 82, 83, 86f), that bright or intelligent children make a more rapid initial adjustment than dull children. If bright, average and dull children react somewhat differently in the successive trials of the same test it is obviously desirable to repeat the tests if we would secure reliable data as to the intelligence differences between different classes of children.

7. The increase in psycho-motor capacity from group to group or from the lowest to the highest group of intelligence for the clinic cases when classified according to B.-S. or chronological age is sometimes greater for the girls and sometimes greater for the boys. Apparently the improvement in the more intelligent groups is on the average slightly greater for the girls than for the boys, but the results are not consistent.

CHAPTER IV

SEX DIFFERENCES IN FORM-BOARD PERFORMANCE

School cases, or normal children

By considering all the separate scores for the bright, average, and dull boys and girls in all the trials and in all the whole-ages from 4 to 17, in Tables I to XV, it is possible to make 148 comparisons (the data are somewhat incomplete in ages 4, 16 and 17). In 70% (101 instances) of these cases boys are superior to girls of the same age, in 27% (44 instances) the girls surpass the boys, and in 2% (3 instances) the scores are equal.

In Table XLVIII, where only the shortest scores are averaged by half-years for ages 4 to 17½ for the two sexes irrespective of the sub-classifications into bright, average and dull, the boys surpass in 73% (19) of the half-ages, and the girls in 27% (7), which gives approximately the same ratio of masculine superiority.

The gross quantitative amount of superiority in all the instances in all the ages (4 to 17), Tables I to XV, in which the boys do better than the girls amounts to 259.1 sec., while the corresponding figure is 63.1 sec. for all the instances in which the girls surpass the boys. The corresponding figures for the half-year scores in Table XLVIII, based on the best records only, are 16.1 and 3.6 sec., and for the whole-year scores in Table XLIX, also based on the best records only, they are 9.7 and .1 sec. (age 8, the only age in which the girls excel). The boys' average amount of superiority for each whole-year for all the comparisons in Tables I to XV amounts to 1.3 sec. (after deducting the girls' gross amount of superiority from the boys' gross amount of superiority). The corresponding average superiority of the boys per whole year, based on the best records (Table XLIX, ages 4 to 17), is about half as large, or .61 sec.,[1] while the superiority for each half-year, based on the best records only (Table XLVIII) amounts to .48 sec.

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[1] Eactly the same figure is obtained by adding all the scores for all the boys and girls separately in the Sh. columns for ages 4 to 17, then dividing each by the total number of boys and girls, and subtracting the girls' average from the boys' average.

The difference amounts to over 1 sec. in five ages: age 5, 1.2 sec.; age 9, 1.3 sec.; age 11, 1.1 sec.; age 16, 1.4 sec.; and age 17, 1.6 sec.

The average or normal (particularly) and bright boys are relatively more superior to average and bright girls, than the dull boys are superior to the dull girls. This is shown by the per cent of cases in Tables I to XV in which the boys or girls excel among the bright, average and dull pupils:

	Bright	Average	Dull
Boys superior:	62%	81.5	56.2%
Girls superior:	37	14.0	40.5
Both equal:	0	3.5	2.2

The average amount of superiority in seconds of time of the average boys compared with the average girls for all ages amounts to .65 sec. The superiority of the bright boys compared with the bright girls amounts to .51 sec. Strangely the superiority in terms of time of the dull boys compared with the dull girls is very much greater, or 2.62 sec. An examination of the tables, however, will show that this result, which is inconsistent with the greater frequency of superior records among the boys, is due to the abnormal results in ages V and VI. If we eliminate these records, since there are only 5 dull boys and 5 dull girls in both of these ages the boys' superiority will be reduced to .28 sec., which is considerably less than the boys' superiority in the average and bright groups.

Bolton, using the tapping test, came to a similar conclusion, namely that the "poor" girls excelled the "poor" boys more emphatically than the "good" girls surpassed the "good" boys. Thus the difference in the number of taps made by the right hand between the good girls and the good boys amounted to only 1.5, while between the poor girls and the poor boys it reached 4.7 taps.[2]

The boys' superiority over the girls' is slightly more frequently apparent in the first two trials than in the third or shortest score, while, contrariwise, the girls' superiority over the boys' appears more frequently during the third trial, as indicated by the following per cents (based on the combined averages for all the bright, dull and average pupils in ages 4 to 17) for the different trials:

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[2] Bolton, T. L. The Relation of Motor Power to Intelligence. American Journal of Psychology, XIV, 1903, p. 615f.

Per cent of averages in which boys are superior to girls				Per cent of averages in which girls are superior to boys			
I	II	III	Sh.	I	II	III	Sh.
68	69	63	66	27	30	34	31

The superiority of the boys over the girls in terms of seconds amounts to 1.77 sec. in the 1st trial,[3] 1.21 sec. in the IId, 1.41 sec. in the IIId, and 1.05 in the averages for the shortest scores. The boys surpass the girls relatively less frequently during the third trial, although the amount of superiority in seconds of time is not reduced (the figure is larger than in the second trial). Apparently boys incline to do their best more frequently at the start than girls do. The boys make a vigorous initial attack more frequently than do the girls. Sylvester makes a somewhat similar observation.[4] It therefore appears that girls tend to gain relatively more than boys from repetition. This being so, it is evident that we cannot discover all the sex differences in the form-board performance by a single trial. We need to give at least three trials. We have seen before that the boys' superiority over the girls' based on the best whole-year scores is only about half as large as their superiority when based on the averages of all the trials (p. 54). We see here again that the superiority in units of time is least for the averages of the shortest scores (1.05 sec.). Accordingly, the best single index with which to express the relative efficiency of the two sexes is the best record in the three trials.

Whether the boys' superiority over the girls' increases or decreases with increasing chronological age does not appear unequivocally from the tabulations. On the basis of the 148 comparisons in Tables I to XV, to which reference is made above, it is found that the boys are superior in 66% of the instances in ages 4 to 10, inclusive (girls superior in 34%), and in 70% of the instances in ages 11 to 17 (girls superior in 25%, equal in 4%). The average amount of boys' superiority per year in the earlier ages (substracting the girls' total amount of superiority from the boys' total amount of superiority and dividing by the total number of instances) amounts to 1.6 sec., but in ages 11 to 17 to only .99 sec. While the older boys surpass the older girls more frequently than the younger boys excel the younger girls, the average amount of the superiority is less for the older than for the younger boys. But this seems to be due to a few abnormal records in the lowest ages. By basing the comparison on the averages for the fastest records only (Table XLIX) we find that the boys' superiority for ages 4 to 10 is .58 sec. per year, as compared with .78 sec. for ages 11 to 17. It appears therefore that the boys' superiority becomes slightly more patent with age—a result that would be in accordance with the alleged fact that girls mature more rapidly than boys, whence they should do relatively better during their younger years.

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[3] These figures are obtained by finding the differences between the boys' and girls' averages in each age, adding the differences for all the ages, and dividing by the number of ages compared.

[4] As before, p. 38.

Sylvester found that the girls excelled at 11 and 12, and the boys at 13 and 14. Our figures do not entirely confirm these findings. In Table XLIX, whole-year averages based on the shortest scores, the boys do a trifle better in all these ages except 14, where the scores are equal. In the corresponding set of half-yearly norms, Table XLVIII, the boys excel slightly in all the ages from 11 (10^{10}-11^{8}) to 14 (13^{10}-14^{8}), but not in 14½. A detailed analysis of all the averages in all the successive trials for the bright, average and dull children, in Tables I to XV, indicates that the girls did relatively better in ages 12, 13 and 14 than in age 11 (where the boys are noticeably superior), although their records were not quite equal to the boys. It would appear, therefore, that the boys drop back somewhat from ages 12 to 14 in psycho-motor capacity, as measured by this test, so that their records are practically the same as the girls. The average difference for these three ages, based on the shortest records (Table XLIX) is negligible, .2 sec. Singularly the record of the 13-year old boys is exactly the same as that of the 12-year old boys; and the record of the 13-year old girls exactly the same as that of the 12-year old girls. Both seem to have reached a "resting plateau" at 13. It may be added that the records for the two sexes are also practically the same for ages 7 and 8.

Clinic cases, arranged according to B.-S. age

The data in Tables XVI to XXVII enable us to make 137 comparisons between the boys and girls in all ages, trials and grades (or classifications) of intelligence exclusive of the averages for "all grades" (four last columns).

In 50% of the comparisons (69) the girls surpass, in 49% the boys (67), and in 1% the scores are equal (1 case).

The total amount of superiority in the instances in which the girls surpass the boys amounts to 387.6 sec., while the corresponding figure for the instances in which the boys surpass the girls is 349.4 sec. The girls' average amount of superiority for each B.-S. year for all the comparisons thus amounts to only .28 sec.

If, however, we compare the combined averages for "all grades" of pupils in each of the ages (the last four columns, 44 comparisons), the boys appear to surpass the girls somewhat in all the trials. The following tabulation gives for each trial the per cent of B.-S. ages in which the boys and girls excel, and the average amount in seconds per B.-S. age by which the boys surpass the girls. The latter was ascertained by computing the amount by which the boys surpassed the girls, or the girls surpassed the boys, in each B.-S. age, adding the remainders of all these differences, subtracting the smaller from the larger of the resulting sums, and dividing by the number of B.-S. ages compared.

Trial:	I	II	III	Sh.
Boys excel:	54%	72%	54%	63%
Girls excel:	45%	27%	45%	36%
Boys' ave. superiority:	2.2 sec.	.57 sec.	—.25 sec.[5]	.50 sec.

Here it appears that the boys excel relatively most frequently in the second trial, although there is a larger quantitative gain (in seconds) in the first trial—due to the dominant influence of the exceptionally large score for the girls in age IV.

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[5] Girls superior to boys.

We may effect another comparison between the sexes by separately adding the totals for all the boys and all the girls in all the ages in each trial, and then divide the resulting sum by the total number of boys and girls recorded in each column. The resulting averages are as follows:

Trial:	I	II	III	Sh.
Boys:	34.4 sec.	26.7 sec.	23.9 sec.	22.3 sec.
Girls:	36.6	27.0	22.7	21.5

Here the boys excel in the first two trials by 2.2 sec. and .3 sec., while the girls excel in the third trial and in the averages of the shortest scores by 1.2 sec. and .8 sec., respectively.

Finally we may calculate the per cents of instances in which the boys or girls excel in each trial separately for the imbeciles, morons, border-line, backward, retarded and normal cases and then average all the results (137 comparisons). It will be seen, again, in the following tabulation that the boys excel in the first two trials more frequently than the girls, while the girls excel more frequently in the third and shortest:

Trial:	I	II	III	Sh.
Boys excel:	52.6	55.	45.	48.
Girls excel:	44.3[6]	44.7	55.	52.

The boys' average superiority over the girls for each B.-S. age amounts to 1.47 sec. and 1.75 sec. in the first and second trials, while the corresponding superiority of the girls in the third trial and the shortest scores (Sh.) amounts to 2.34 sec. and 1.32 sec.

While the results from both the clinic and the school cases show that the boys relatively to the girls do better during the first two trials, and the girls relatively to the boys do better during the third trial and in the averages for the shortest scores, there is a discrepancy between the two groups in respect to the sex difference in general efficiency in the form-board performance.

Among the clinic cases the two sexes are more nearly alike in average performance, sometimes the girls' averages are better, sometimes the boys'; in some trials the girls excel, in others the boys. All in all, the girls' records possibly tend to be slightly better. On the other hand, among the school cases the boys clearly excel, although, of course, there are many individual instances in which girls surpass boys of the same age, and although the average difference for all ages varies in the different trials from less than 2 sec. to less than 1 sec. What is the explanation of this discrepancy? Possibly it can be explained on the basis of the assumption, generally held, that backwardness affects boys more seriously than it does girls.[7]

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[6] Both sexes equal, 2.6%.

This assumption, however, is capable of a two fold interpretation: first, that backwardness is more *frequent* among boys than among girls; i. e., that there is a larger number of backward or mentally defective boys than girls. This supposition, which is commonly held, is merely a phase of the familiar theory that there is greater variability in the male sex than in the female sex. Thus Havelock Ellis: "From an organic standpoint . . . . women represent the more stable and conservative element in evolution." The male shows greater variability "for almost the whole of the field we have covered," and this has "social and practical consequences of the widest significance."[8] Or Patrick: "Woman is less modified than man and presents less variation. . . . . She is more conservative, representing the child type, which is the race type . . . . man, on the other hand, represents variation. The mental powers peculiar to advancing civilization are more developed in him."[9] Or Münsterberg: "Women are nearer the average type. The extreme variations above and below the average occur more frequently with men. They show the greatest development of intellectual, emotional and volutional powers in the case of scientific or artistic or political or religious genius and the greatest criminal depravity."[10]

This doctrine, which harks back to Darwin's conclusion that the secondary sexual characters in domesticated animals are more variable in the male sex, has been attacked by Pearson who regards it as a piece of "pseudo-scientific superstition,"[11] and more recently by Montague and Hollingworth[12] on the basis of 10 anatomical measurements of infants at birth.

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[7] Thus Bolton, T. L., as before. Bolton investigated the relation of motor power to intelligence in 60 good and 60 poor pupils.

[8] Ellis, Havelock. Man and Woman, 1909.

[9] Patrick, G. T. W. In Quest of the Alcohol Motive, Popular Science Monthly, 1913, Sept.

[10] Münsterberg, Hugo. Psychology, General and Applied, 1914, 232.

[11] Pearson, Karl. Variation in Man and Woman, 1897 (Chances of Death).

In case this theory were true it is evident that we should find a predominance of both subnormal males and supernormal males in any considerable array of unselected males and females.

Second, that the degree of backwardness affects boys more *intensely* than girls. This means either that there are relatively more boys than girls among the *lowest degrees* of defectives (say, idiots and imbeciles[13]); or that the inferior grades of boys are inferior to the inferior grades of girls, while the superior grades of boys are superior to the superior grades of girls.

If these suppositions are to account for the sex discrepancy found in our two groups of cases it must be shown definitely: either (a) that there are relatively more subnormal[14] boys in proportion to the number of subnormal girls in the clinic group than in the school group; or (b) that there is a greater prevalence of subnormal boys, particularly of the lower grades, in the clinic group than subnormal girls in the clinic group; or (c) that the lower the boys rank in the scale of intelligence the more decidedly deficient are they than girls of a similar stage of intelligence.

If it can be shown that hypothesis (a) *or* (b) or (a) *and* (b) are correct, the discrepancy would be explained without the need of invoking (c), since our results have shown that subnormal children are less efficient in form-board performance than normal or supernormal children. We shall consider the last supposition (c) first.

In the following tabulation is given in the first two lines the per cent of instances in all the trials of the form-board in which the boys surpass the girls, and the girls surpass the boys in the different intelligence classifications, together with the average amount of superiority per B.-S. age (third line) of the one sex over the other in seconds, based on the Sh. averages (a minus sign indicates that the girls are superior):

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[12] Montague, Helen, and Hollingworth, Leta Steffer. The Comparative Variability of the Sexes at Birth. The American Journal of Sociology, XX, 1914, 335 f.

[13] "Imbeciles are more frequent among boys, but the mortality is higher with imbecile girls": Warner, Francis. The Study of Children, 1907, 245.

[14] I use the word to include all grades classified below normal or average.

	Imbeciles	Morons	Border-line	Backward	Retarded	Normal	Bright
Boys excel:	64%	40%	50%	50%	62%	35%	0%
Girls excel:	36%	60%	50%	49%	33%[15]	65%	100%[16]
Superiority in sec.:	.27	—2.8	—.36	—1.4	—.56	—3.1	—1.4

Here it appears that the normal boys have a poorer record than any other group of boys relatively to the girls' scores, and the imbecile boys relatively to the girls have the best records. The boy morons, however, do poorer than the higher grades of subnormal cases (border-line, backward, and retarded), relatively to the girls of the same grade. It is therefore apparent that the evidence as to the inferiority of the inferior boys is by no means conclusive.

In another connection, however, data have been supplied for a number of B.-S. and other tests administered to 333 male and female epileptics, which make it possible to compare the records of each test for the two sexes in each B.-S. age tabulated. From the printed tables[17] it is possible to compute the differences between the males and the females for the lower half and the upper half of the B.-S. ages in which the results for each test are recorded. We can thus determine whether the lower intellectual grades of males are inferior or superior to the lower grades of females to a smaller or greater extent than they are inferior or superior to the higher grades of females. The following tabulation gives the amount of superiority of the females over the males for the lower and higher B.-S. ages. The figures have been obtained by computing the sex differences in each B.-S. age, then adding separately (a) the instances in which the males excel and (b) the instances in which the females excel, then subtracting the smaller total from the larger, and dividing the remainder by the number of B.-S. ages included in the comparison. The tests compared here are the form-board and the following B.-S. tests: naming the four colors, reading the selection about a fire, reproduction of memory units from the selection thus read and the number of detached words uttered in 3 minutes. The females surpass the males in these tests by the following amounts:

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[15] Equal 4%.

[16] Based on meager data.

[17] Tables X, XI, XV, XVII, XIX and XXII, in Experimental Studies of Mental Defectives, pp. 68-91. The data tabulated are not always sufficiently extensive in all the tabulations to render the results entirely trustworthy.

Test:	Lower B.-S. Ages	Upper B.-S. Ages
Form-board:	23.8 sec.	.12+[18]
Four colors:	3.3 sec.	2.1
Reading selection:	8.4 sec.	1.7
Memory units:	.03 units	1.4+
Detached words:	1.3 words	1.5+

It is apparent that the lower grades of females without exception do relatively much better than the higher grades of females, as compared with the low and high grade males, so that for this particular group of epileptics the theory is sustained: the inferior grades of men are relatively inferior to the inferior grades of women, in all the tests analyzed. Even should further investigation demonstrate that this conclusion is valid for the epileptic class in general, this would not necessarily prove that it applies to other types of deviates from normal mentality, such as retarded, backward or feeble-minded cases. Owing to the discrepancy on this point in the data presented above this question cannot be considered to be finally closed. It remains a fertile field for experimental investigation in future.

Turning, now, to the first supposition: (a) what is the relative percentage of boys and girls in the two groups in the different intelligence classifications? The percentage distribution of the different classifications of boys (based on the total number of boys) and girls (based on the total number of girls) in the clinic and school cases is as follows:

	Clinic Cases		School Cases	
	Boys	Girls	Boys	Girls
Subnormal:[19]	87.95	80.43	12.8	12.7
Normal:	10.22	9.77	76.9	73.7
Supernormal:[20]	1.59	9.77	10.1	13.5

[18] The + sign indicates that the males surpassed the females.

[19] All cases classified as below normal or average.

[20] All cases classified as above normal or average.

It is apparent on cursory inspection that the proportion of subnormal boys relatively to the number of subnormal girls is perceptibly greater in the clinic than the school group; and that the number of supernormal boys relatively to the number of supernormal girls is considerably less in the clinic than in the school group. Our finding, namely, that the clinic boys compared with the clinic girls do relatively poorer than the school boys compared with the school girls, is thus in accordance with expectation.

Incidentally it may be observed here that in the Bellefield School there were more boys (9.1%) than girls (6%) rated as bright, but more girls (86%) than boys (81%) rated as average, and more boys (9.1%) than girls (8%) rated as dull; while in the Holmes School the percentage of average pupils was about the same for the boys (82%) and for the girls (81%), and likewise the percentage of dull cases (boys 18%, girls 18.8%). These curves of distribution are quite in contrast with the school statistics of retardation and elimination. A study of 15 city school systems showed that there were 13% more retardates and repeaters among the boys than among the girls, and 17% more boys than girls were eliminated.[21] Of consecutive cases, largely juvenile, clinically examined by the writer in university and public school clinics—most of whom were sent either because of suspected feeble-mindedness or because of pedagogical retardation—70.8% were males and 29.1% females. Of the present enrollment (February 1, 1915) in the special schools in St. Louis 71.8% are boys and only 28.1% are girls. Of 520 pupils who had been in three subnormal classes in Chicago 87.7% were boys and 12% girls. (It has been claimed that the children in these classes are backward rather than feeble-minded.) The average number of "suspects"—candidates reported by principals for special classes in Paris—was 3.7% of the pupils in 10 girls' schools and 5.35% of the pupils in 8 boys' schools. These statistics uniformly indicate that there are more subnormal boys than subnormal girls. The explanation is frequently made that this is not due to an actual preponderance of subnormal boys, but to the greater readiness of school authorities to report boys than girls for special schools, partly because the subnormal boys are more troublesome. No facts, however, have been produced proving that this actually is the case. It is a well known fact that there are more boys than girls in most of the feeble-minded institutions and colonies. Of the 24,737 inmates in the state institutions of the United States in 1912-13, 13,077 were males and 11,660 were females. Here, again, the claim is made that the preponderance of boys is due to the greater reluctance of parents to part from their defective female offspring. It should be emphasized, however, that among our unselected school cases from the Bellefield and Holmes schools there is no noticeable excess of subnormal boys.

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[21] For a recent study of the comparative amount of retardation among the two sexes, see Hill, David Spence. Measurements in Elementary Education. Department of Superintendence, New Orleans Public Schools, 1914, 16f, 20, 27.

Turning, finally, to the second supposition (b): the tabulation on p. 63 shows that, while there are .45% more normal boys than normal girls among the clinic cases, there are 7.52% more subnormal boys than subnormal girls, and 8.18% less supernormal boys than supernormal girls. The following tabulation shows that there are relatively slightly more of the lowest grades (idiots, imbecile) among the boys, a larger proportion of the middle grades (morons and border-line) among the girls, and a larger proportion of the upper grades of subnormal (backward or retarded) among the boys:

	Subnormal	
	Boys	Girls
Idiots:	.63	.00
Imbeciles:	12.14	11.27
Morons:	13.73	17.29
Border-line:	12.46	12.78
Backward:	32.70	30.82
Retarded:	16.29	8.27

In a prior classification by the B.-S. scale of a village of epileptics we found a "larger percentage of high-grade males[22] than females. Although there are slightly more male than female idiots (.7% more), the male imbeciles are fewer (by 7%), while the male morons (by 4.8%) and male retardates (by 1.4%) are more numerous. Likewise if we consider the separate columns, there are less men than women idiots (by 2.1%) and less men than women imbeciles (by 2.4%), but more men morons (by 3.1%) and retardates (by 1.3%); while "there are more boy than girl idiots (by 5.7%)," there are "decidedly less boy imbeciles (by 20.8%) and decidedly more boy morons (by 11.5%) and retardates (by 3%)." The obvious superiority of the boys is confirmed by the above figures, although a relatively large percentage of the idiots are boys. Likewise the average amount of retardation was greater for the epileptic girls than for the epileptic boys, from chronological ages 1 to 13 by an average of .8 years, and from the chronological ages from 14 to 20 by .9 years. The boys showed less retardation than the girls in the following B.-S. ages by the average amount in years indicated by the figure following the B.-S. age, which is given in Roman characters: II, 3.5; III, .3; VI, 3.8; VII, 2.0; VIII, 1.0; and XI, 1.4. The girls were retarded less than the boys in the following B.-S. ages by the amount indicated: IV, 2.2; IX, 2.7; and X, .4.[23] Subtracting the sum of the latter from the sum of the former and dividing by the number of B.-S. ages, leaves .74 of a year as the average amount by which the boys are retarded less than the girls.

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[22] Experimental Studies of Mental Defectives, p. 99ff. The males include both the boys (under 21) and the men (21 and over), and the females the girls (under 21) and the women (21 and over).

It is, of course, possible that females preponderate among the low grade epileptics and males among the low grade feeble-minded, while the males preponderate among the highest grades of subnormals (backward and retarded cases) and epileptics, but the available data are inadequate to demonstrate this conclusion.

Sylvester reports that the boys in the special classes for the backward and the feeble-minded in the Philadelphia public schools were decidedly superior to the girls in form-board performance (by an average of 5.9 sec.), and attributes this to the fact that the "girls of these classes, as a group, are more backward than the boys,"[24] the girls with a mentality equal to the brightest boys being left in the regular grades. Unfortunately no tabular data are supplied to prove that there actually was a preponderance of low grade girls in the groups studied, or that the low grade girls did poorer than the low-grade boys.

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[23] As before, p. 102.

[24] As before, 16.

It is evident from the foregoing analysis that the questions as to whether there are numerically more subnormal males than females, whether there are more males than females in the extreme classifications, and whether the low grade males are relatively inferior to low-grade females while high-grade males are relatively superior to high-grade females, have not yet been conclusively established. In order definitely to solve these questions it will be necessary in future to classify by exact objective methods and subject to varied tests large and varied groups of unselected males and females. No such studies have thus far been prosecuted on an adequate scale and subjected to adequate mathematical treatment.

However, the fact that the subnormal boys are relatively more frequent than the subnormal girls in our clinic cases than in our school cases, and the fact that there are relatively more subnormal boys than subnormal girls in the clinic group, would seem adequately to explain why the clinic boys do poorer than the school boys relatively to the girls. But before definitely accepting this explanation we must examine another contingency which, if true, might in itself account for the relative inferiority of the clinic boys. This is the possibility that the average chronological age of the clinic girls may be greater than that of the clinic boys of the same intelligence classification—possibly due to the alleged greater reluctance of the parents and the schools to send backward girls than backward boys to special classes or to the clinic for examination. The average chronological age of all the boys and girls in each classification is as follows:

	Imbeciles	Morons	Borderline	Backward	Retarded	Normal	Bright	Average
Boys:	10.30	13.31	12.75	11.55	9.60	8.78	5.46	11.28
Girls:	11.54	13.72	12.23	11.14	11.01	8.65	7.79	11.19

While the boys' and girls' averages for all the groups are practically the same, the girls are older than the boys in 4 of the 7 classifications. In two of the groups where the girls are older the boys excel more frequently than do the girls (imbeciles, retarded[25]) but, contrariwise, the girls also excel more frequently than do the boys in two groups (morons and bright). On the other hand, in one of the groups where the girls are younger, the boys and girls excel equally frequently, although the average gain in seconds is slightly greater for the girls (border-line), in the second group the boys excel slightly more frequently, but the average gain is greater for the girls (backward), and in the third group the boys do decidedly poorer than the girls. It is thus clear that the discrepancy cannot be referred to the difference in chronological age between the two sexes, but to the relative preponderance of subnormal boys in the clinic group.

Since there is a preponderance of subnormal boys in the clinic cases, the conclusion seems to follow that if feeble-minded boys and girls of the same degree of intelligence are compared the feeble-minded boys will slightly excel the feeble-minded girls, just as we have found to be the case with normal boys and epileptic males. Epileptic "males excel in the form-board test," "particularly in the average for the high-grade patients, and in the average and M.V. for the boy morons."[26] In the general average the epileptic boys surpass the girls by 20.9 sec., and the men the women by 8.7 sec.[27]

From the foregoing analysis it is evident that in order to secure legitimate comparative data on the efficiency of the two sexes in respect to any given trait it is necessary to test an equal number of the same mental grades of boys and girls. Little, if any, heed has been given to this warning by the experimental psychologists—aside from comparing boys and girls of the same chronological age. Some experimental pedagogists when testing the doctrine of formal discipline have, however, attempted a division of squads into groups of equal capacity, but these have been mixed squads (containing both sexes). If we test a preponderance of backward girls and a preponderance of bright boys it is quite manifest that our conclusions as to masculine superiority may be wholly erroneous.

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[25] The average gain in seconds, however, is greater for the girls in the retarded group.

[26] As before, 99.

[27] The results are discrepant for the males and females.

General Results and Conclusions

1. Boys are superior to girls in psycho-motor capacity as measured by this form-board, the average difference for each whole-year amounting, for all trials, to 1.3 sec., and for each half-year, based on the Sh. scores, to .48 sec. In Graph II the boys' curve is uniformly better than the girls' from age 8½ to 14, except in age 10, where the curves practically overlap. The curves after age 15 are based on too few cases to permit of any conclusion.

The subnormal boys and girls (clinic cases), however, are more nearly alike in form-board performance. The girls slightly excel when the comparison is confined to the separate successive groups of intelligence; while the boys excel when it is based on the averages for "all grades" of intelligence. The reasons why the subnormal girls did relatively better than the normal girls are: first, there were relatively more subnormal clinic boys than subnormal school boys; second, there were relatively more subnormal clinic boys than subnormal clinic girls, and less supernormal clinic boys than supernormal clinic girls; and third, there were relatively slightly more low grade subnormal boys (idiots, imbeciles) than low-grade subnormal girls. The latter advantage for the girls may, however, be offset by the fact that there were relatively more boys than girls in the highest subnormal categories (backward and retarded). Detailed analysis of the data shows that a possible difference in the chronological ages between the boys and the girls is an entirely negligible factor.

2. The boys' superiority over the girls apparently becomes more marked with increasing chronological age, although the evidence is not absolutely conclusive. The boys' superiority is shown visually in Graph II, based on the half-yearly classification as explained on page 4. The boys' curve is superior in 19 and the girls' in 7 of the 26 half-ages which permit comparison (no data are available for the boys in age 17 and for the girls in age 16½. The girls are slightly superior to the boys in age 6 instead of inferior, as shown in the curve). In no age where the data are adequate does the difference amount to two seconds. This result, however, would be in accordance with expectation,

on the assumption that the greater maturity of the girls compared with the boys is more marked during the early years of childhood, becoming gradually less and less marked as the girls grow older.

3. The superior normal boys excel the superior normal girls more frequently and decidedly than the inferior normal boys excel the inferior normal girls. The bright and average boys surpass the bright and average girls in 62% and 81.5%, respectively, of the comparisons, and by an average of .51 sec. and .65 sec., while the dull boys surpass the dull girls in only 56.2% of the comparisons and by an average of .28 sec.

Our data are somewhat discrepant with respect to the question as to whether the inferior grades of feeble-minded males are inferior to the inferior grades of feeble-minded females. On the other hand, a comparison of the records in five tests given to institutional cases of epilepsy shows that the lower grades of males do relatively much worse than the higher grades of males compared, respectively, with the lower and the higher grades of females.

Our results suggest, but they do not conclusively prove, that the male sex varies more than the female sex, for while our superior boys vary more than the superior females both among the normals and among the epileptics, and while our inferior males vary more than the inferior females among the epileptics, our inferior males among the feeble-minded (clinic cases) do not always vary more than the inferior feeble-minded females. It is evident that we must collect additional data on an extensive scale before we can make categorical pronouncements upon the moot question of the relative variability of the two sexes.

4. Closely related are the questions as to whether there are numerically a larger percentage of subnormal males than subnormal females, and a larger percentage of the lower grades of males than the lower grades of females. Our data, in the main, tend to support the affirmative answer usually given to this question. We find far more boys than girls in the special classes in St. Louis; far more boys than girls have come to the author's clinic for examination during the last three years, of whom the

great majority have graded below normal; a larger percentage of the boy than the girl clinic cases whose records have been compared in this form-board study were subnormal, and fewer boys than girls rated as supernormal; and among the "school" cases studied in this investigation more boys than girls were classed as dull and less were classed as bright. Moreover, public school statistics of retardation generally reveal a larger percentage of boy than girl retardates. Likewise, in the study of a village of epileptics we found a slight preponderance of male idiots over female idiots, but the average amount of retardation was greater for the girls (by .74 of a year), possibly due to the fact that there were relatively less male than female imbeciles, and more male than female morons and retardates.

The tentative inference from our data, that there is a numerical preponderance of subnormal males over subnormal females, but that the abler males surpass the abler females, invites experimental verification or refutation upon an extensive scale.

5. In order to arrive at legitimate conclusions in regard to the mental differences between the two sexes it is necessary to test approximately equal numbers of boys and girls, or men and women of the same grade of intelligence. Wholly erroneous inferences would be deduced from tests based on a preponderance of inferior males and a preponderance of superior females.

6. Both the normal and the subnormal boys surpass the girls more frequently or more emphatically in the first or the second trial than in the third trial. Boys overcome the initial lag or inertia faster, or make a more vigorous initial attack, in the form-board test than girls. Accordingly the girls gain relatively more on their initial records from repetition. Because of this fact it is, again (see pp. 32, 53, 99) desirable in measuring the mental differences between the sexes to give the same tests more than once. In this test if three trials are given the best record of the three offers the fairest index of performance by which to compare the two sexes.

7. Boys and girls seem to reach a resting plateau at the same points, namely, ages 8 and 13. The records at age 13 are the same for both sexes as at age 12, while the records at 8 are prac-

tically the same for both sexes as at 7. We do not find, in harmony with an earlier finding that the boys' curve is actually inferior to the girls' curve at 12, and superior at 13 and 14, but that it is practically the same at 12 and 13 and precisely the same at 14. While the boys thus stagnate somewhat during these years, they still keep well abreast of the girls. We likewise find that the boys are clearly superior, instead of inferior, to the girls at 11. Warner made the observation that "In school the proportion of those who are dull at eleven years and older is higher with girls."[28]

The reasons for the arrest in the curves at ages 8 and 13 are not obvious. It may be due to retarded or accelerated changes in the growth curve. But if this is the explanation why do not the arrests come at different points for the boys and the girls? The period of accelerated growth in height is alleged to come at 7 for girls and 8 for boys, the period of diminished growth at about 9 for girls and 11 for boys, and the period of maximal growth at 13 for girls and 15 for boys. In weight the arrest is said to be most pronounced at 9 for girls and 11 for boys, while the greatest increase comes at 13 or 14 for girls and 16 for boys. The customary ascription of accelerations or retardations in mental developmental age-curves to corresponding physiological accelerations or retardations still rests, I believe, upon assumed premises, rather than on demonstrated evidence.

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[28] As before, p. 246.

CHAPTER V

THE INFLUENCE OF FAMILIARITY AND REPETITION ON PSYCHO-MOTOR ABILITY

There is a number of factors which make for an increase in efficiency in this type of test in the second and third trials. These factors are, first, initial lag and "warming up." Experiments have shown that there is a period of inertia at the beginning of work during which the individual is struggling to become better adjusted, followed by a period of rapid adjustment or heightened effectiveness. Second, familiarity. In this experiment this consists in the better perception or discrimination, largely visual, during the repeated trials of the solid or hollow forms (particularly on the part of the low grade subjects), the knowledge of the locations of the recesses in the board, and the association of the corresponding blocks with these locations. Third, motor facilitation, or the improved facility of grasping the blocks, handling the blocks and of placing them rapidly and accurately in the proper recesses during the repeated trials (a factor whose influence is quite obvious in the lower grades). Fourth, heightened effort, due to confidence and encouragement born of the initial success, and the stimulating appeals from the experimenter. Fifth, final spurt. The knowledge that the third was the final trial tended, no doubt, to stimulate many of the subjects to put forth unusual effort during this trial. All of these factors are elements of the practice curve—although theoretical scruples may be advanced against considering an improvement curve as a practice curve when there are only two repetitions.

The following factors would tend to produce a loss of efficiency in the later trials. First, fatigue. Because of the fact that there were only three trials in all, this factor is probably negligible except in those lower grade cases who required a long time to do the test. Second, discouragement, because of difficulty to do the test properly the first time, sometimes observable in low grade cases. Third, confusion. Some children get confused when hurried too much, observable in children of all types, but particularly in the lower grades and in the cases manifesting the confusion phenomena of the epileptic, the disequilibrated or alienated. Fourth, stubbornness or refusal to put forth greater and greater effort, very rarely observable. An occasional child will deliberately refuse to accelerate his speed, sometimes because of egotistic contempt for the test.

School cases, or normal children

The analysis of the successive records will be confined to the whole-year averages.

That the great majority of the school cases improved with each successive trial appears very clearly from the following facts, based on the separate comparison of the bright, average and dull pupils in the successive trials (120 comparisons in Tables I to XV):

Eighty-two per cent of the best averages (fastest speeds) were made during the third trial, and only 15% during the second, and 2.5% during the first trial. Contrariwise 92% of the poorest averages (slowest speeds) were made during the first trial and only 5% during the second, and 2.5% during the third trial. Necessarily the average records (intermediate speeds) were made in the second trial; actually 82% are found here, as against 12% in the third and 5% in the first trial.

Based on the combined averages[1] for the bright, average and dull boys and girls in Tables I and XV, we find that in all ages without exception all the slowest performances were made during the first trial, all the intermediate during the second and all the fastest during the third trial. If the averages in the third trial are compared with the averages for the shortest scores (Sh. column) it is found, again, that the latter are faster in all ages except one (age seventeen, where they are equal).

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[1] These averages were not computed by averaging the averages for the bright, average and dull pupils and dividing by three, but by totalling the scores for all the pupils within the whole-age classification and dividing by the total number of cases. This complete method of computing the final averages (which alone is precisely accurate) has been employed in all cases, except the final averages for the M.V.'s.

The amount of the improvement may be expressed in two ways: first, in terms of the difference in seconds between the fastest and slowest averages, or between the averages of the first and third trials, or between the averages for each successive trial; and, second, in terms of five indices of improvement (f). The first index is computed by dividing the different averages in the first trial into the corresponding averages in the second trial $(f\frac{2}{1})$; the second, by dividing the averages in the second trial into the corresponding averages in the third trial $(f\frac{3}{2})$; the third, by dividing the averages in the third trial into the corresponding averages for the shortest (Sh.) scores $(f\frac{\text{Sh.}}{3})$; fourth, by dividing the averages in the first trial into the corresponding averages in the third trial $(f\frac{3}{1})$; and fifth, by dividing the averages in the first trial into the corresponding averages for the shortest scores $(f\frac{\text{Sh.}}{1})$. Since these records are based on time performances, an index less than unity (1.00) indicates a gain while an index in excess of unity indicates a loss. The difference between the index and unity may be taken as the percentage of loss or gain.

The improvement between the slowest and fastest successive averages, based on the combined averages of the bright, average and dull pupils (which accordingly means between the first and third trials) amounts in seconds to the following for each age:

Age·	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Gain:	16.3	13.6	8.7	6.	3.8	3.6	2.4	2.2	1.8	2.	1.7	2.4	2.1	2.4

The average improvement per age for the 14 years is 4.9 sec. The average for the three lowest ages is more than 2½ times as large (12.8 sec.), while for the eight highest ages it is not quite half as large (2.1 sec.).

The indices of improvement are as follows for each age:

Ages:	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Ave.
$f\frac{2}{1}$:	.69	.71	.78	.80	.87	.87	.89	.91	.90	.90	.92	.89	.90	.88	.85
$f\frac{3}{2}$:	.93	.92	.91	.95	.94	.93	.96	.94	.97	.95	.96	.93	.93	.90	.93
$f\frac{\text{Sh.}}{3}$:	.91	.82	.97	.99	.94	.96	.94	.94	.93	.94	.93	.97	.91	1.00	.94
$f\frac{3}{1}$:	.65	.67	.69	.77	.80	.81	.86	.87	.88	.86	.87	.82	.84	.80	.79
$f\frac{\text{Sh.}}{1}$:	.60	.61	.69	.72	.77	.79	.81	.81	.82	.82	.82	.80	.78	.80	.76

(The indices have the same meaning as on page 75.)

Taking the averages for all ages (right hand column above) the per cents of increase are as follows: 15% for the second trial compared with the first; 7% for the third compared with the second; 6% for the shortest averages compared with the third trial; 21% for the third compared with the first trial; and 24% for the shortest averages compared with the first trial.

Finally if we compute the average time in each trial for all the pupils in all the ages we get the following figures:

Trial:	I	II	III	Sh.
Averages:	20.8 sec.	17.5 sec.	16.6 sec.	15.7 sec.

The difference between I and II is 3.3 sec.; between II and III .9 sec.; between III and Sh., .9 sec.; between I and III, 4.2 sec.; and between I and Sh., 5.1 sec. The indices and per cents of improvement are as follows:

$f\frac{2}{1}$	%	$f\frac{3}{2}$	%	$f\frac{\text{Sh.}}{3}$	%	$f\frac{3}{1}$	%	$f\frac{\text{Sh.}}{1}$	%
.84	16	.94	6	.94	6	.79	21	.75	25

Basing our comparison upon the performances of the average pupils only the gains, in seconds of time, between the fastest and slowest of the three successive averages in each age are as follows:

Ages:	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Gains:	17.6	16.2	9.2	4.7	3.6	3.7	2.5	2.2	1.9	2.1	1.7	1.1	2.5	2.4

The average improvement per age for all ages is 5.1 seconds. It is about seven times as large for the three lowest ages (14.3 sec.) as for the eight highest ages (about 2 sec.).

The indices of improvement, based on the records of the average pupils, are as follows:

Ages:	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Ave.
$f\frac{2}{1}$:	.70	.65	.76	.81	.87	.87	.88	.91	.90	.91	.93	.95	.87	.84	.84
$f\frac{3}{2}$:	.89	.93	.93	.95	.95	.92	.97	.94	.96	.94	.93	.96	.94	.95	.94
$f\frac{\text{Sh.}}{3}$:	.96	.93	.96	.94	.94	.97	.94	.94	.94	.95	.94	.92	.92	1.00	.94
$f\frac{3}{1}$:	.62	.61	.71	.78	.82	.80	.85	.86	.87	.85	.87	.91	.82	.80	.79
$f\frac{\text{Sh.}}{1}$:	.58	.57	.68	.73	.78	.78	.80	.81	.82	.81	.82	.85	.75	.80	.75

Taking the averages for all ages the percentage of increase in the second trial over the first amounts to 16%; of the third over the second, 6%; of the shortest scores over the third, 6%; of the third over the first, 21%; and of the shortest scores over the first, 25%. These figures are approximately the same as those given for the corresponding indices on pp. 76. They uniformly show that a very considerable increase in efficiency occurs in this test from only two repetitions, about three-fourths of the improvement during these repetitions occurring in the second trial.

Based on their initial records, the average pupils (above) improved appreciably more than the dull or bright pupils, while the dull improved about the same or slightly more on their first records than did the bright pupils, as shown by the following indices and per cents of improvement:[2]

	$f\frac{2}{1}$	%	$f\frac{3}{2}$	%	$f\frac{\text{Sh.}}{3}$	%	$f\frac{3}{1}$	%	$f\frac{\text{Sh.}}{1}$	%
Bright:	.89	11	.94	6	.93	7	.85	15	.80	20
Dull:	.88	12	.94	6	.92	8	.84	16	.77	23

On the basis of the fourth index ($f\frac{3}{1}$) the average pupils gained 6% more than the bright and 5% more than the dull. That the average pupils gain most is probably due to the fact that the bright pupils are able to function very efficiently from the start, hence cannot evince so large a gain in later tests. On the other hand, the dull pupils ought to show a large gain because they make a poor initial start. But the figures show that they are unable entirely to overcome their initial handicap, although they improve relatively a trifle more than the bright pupils. The bright pupils fail to improve as much as the average because of their high initial efficiency, but the dull pupils improve less than the average because they are unable to overcome their inertia. That the dull pupils actually made a larger ratio of their fastest records in the first and second trials, a larger ratio of their slowest records in the second and third trials and a larger ratio of their intermediate records in the first and third trials, than did the bright and average pupils, is shown in the following tabulation, in which is given the percentage of the fastest, slowest and intermediate averages which come in the first, second and third trials, for the bright, average and dull pupils:

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[2] Based on ages 5 to 16, inclusive.

Distribution of Fastest Averages

	First trial	Second trial	Third trial
Bright:	0%	15%	85%
Average:	0%	7%	93%
Dull	8%	15%	77%

Distribution of Slowest Averages

	First trial	Second trial	Third trial
Bright:	100%	0%	0%
Average:	100%	0%	0%
Dull:	77%	15%	8%

Distribution of Intermediate Averages

	First trial	Second trial	Third trial
Bright:	0%	84%	15%
Average:	0%	92%	7%
Dull:	15%	69%	15%

For the bright and average pupils *all* of the slowest averages come in the first trial, but for the dull 23% come in the second and third trials. For the bright and average pupils *none* of the fastest averages come in the first trial, while for the dull 8% come in this trial.

The effect of repetition is very much greater for the seven younger ages (4 to 10) than the seven older ages (11 to 17), as shown by the following indices and per cents of improvement:

	$f\frac{2}{1}$	%	$f\frac{3}{2}$	%	$f\frac{\text{Sh.}}{3}$	%	$f\frac{3}{1}$	%	$f\frac{\text{Sh.}}{1}$	%
Younger ages:	.80	20	.93	7	.93	7	.75	25	.71	29
Older ages:	.90	10	.94	6	.94	6	.84	16	.80	20

The difference between the indices for the older and the younger groups amounts to 10% for the first index; 1% for the second index, 1% for the third index, 9% for the fourth index, and 9% for the fifth index ($\frac{\text{Sh.}}{1}$). The younger children uniformly improve from repetition relatively more than older children, particularly from the first repetition.

The gain among the average pupils is likewise very much greater for the seven younger ages (4 to 10) than among the seven older ages (11 to 17), as shown by the following per cents of improvement:

	$f\frac{2}{1}$	%	$f\frac{3}{2}$	%	$f\frac{\text{Sh.}}{3}$	%	$f\frac{3}{1}$	%	$f\frac{\text{Sh.}}{1}$	%
Younger ages:	.79	21	.93	7	.94	6	.74	26	.70	30
Older ages:	.90	10	.94	6	.94	6	.85	15	.81	19

The difference in the per cent of improvement amounts to 11% in the first, fourth and fifth indices, 1% in the second, while the gain is the same in the third index. Younger children improve relatively more on their initial records from one repetition than do older pupils. The latter gain relatively almost as much as the former from a second repetition; *i. e.*, the gain in the third trial compared with the second is almost as large for the older as for the younger cases.

The young bright or dull children also improve more on their initial records than do the older bright or dull pupils. But the difference between the young bright children compared with older bright children is smaller than the difference between the young dull children compared with the older dull children, as is evident from the following indices of improvement (except $\frac{\text{Sh.}}{3}$):

	$f\frac{2}{1}$	$f\frac{3}{2}$	$f\frac{\text{Sh.}}{3}$	$f\frac{3}{1}$	$f\frac{\text{Sh.}}{1}$
Bright					
Younger[4]	.88	.92	.93	.82	.77
Older[5]	.91	.96	.94	.88	.84
Difference	.03	.04	.01	.06	.07
Dull					
Younger[4]	.85	.88	.92	.77	.70
Older[5]	.90	1.00	.92	.91	.84
Difference	.05	.12	.00	.14	.14

The difference between the dull groups is about twice as great as the difference between the bright groups. The explanation is probably the following. The younger bright child already makes a fairly effective initial adjustment in this test. He has the intelligence needed to rapidly adjust himself to the problem. Accordingly the older bright child cannot markedly improve upon the younger bright child's initial efficiency; nor can he improve as much from repetition as his younger brother, because he is operating nearer the maximal limit of human possibility in this test.

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[4] Ages 5 to 10. [5] Ages 11 to 16.

On the other hand, the younger dull child does not have the necessary intelligence to make a very effective initial adjustment to the problem. He has to learn to identify the blocks and to locate the recesses. This he succeeds in doing measurably successfully during the first and second trials. Hence he shows a large gain during the second and third trials—a gain due perhaps more to his improved recollection of the location of the recesses than to motor acceleration. The older dull child, however, has sufficient intelligence to readily associate the blocks and their corresponding recesses, hence he does relatively better during the first trial and therefore does not improve so much during the subsequent trials. His improvement would probably depend primarily upon increased motor facilitation (speed), while the improvement of the younger dull child would depend upon increased motor facilitation plus improved perceptual and recognitive factors.

Clinic cases, arranged according to B.-S. age

The analysis is based on the figures for "all grades" for both sexes combined in Tables XVI to XXVII (last four columns).

Eighty-two per cent of the best averages were made during the third trial and only 18% during the second, while, likewise, 82% of the intermediate or average records were made in the second trial, and only 18% in the third trial. All the poorest records are found in the first trial.

The amount of improvement in seconds of time between the best (fastest) and poorest (slowest) of the three successive averages amounts to the following for each successive B.-S. age:

B.-S. Age:	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Gain:	32.	56.3	19.3	13.4	11.6	9.0	7.0	5.9	4.8	7.7	3.7

The average improvement for all ages is 15.5 sec., which is three times as large as the corresponding improvement for chronological ages 4 to 17 for the school cases. The improvement diminishes fairly regularly from year to year. It is 4½ times as large for the five lower ages (26.5 sec.) as for the five upper ages (5.8 sec.).

The indices of improvement are as follows:

B.-S. Ages:	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	Ave.
$f\frac{2}{1}$:	.65	.61	.78	.78	.74	.77	.76	.79	.82	.75	.79	.75
$f\frac{3}{2}$:	1.02	.79	.88	.89	.91	.91	.95	.92	.92	.89	1.02	.92
$f\frac{\text{Sh.}}{3}$:	.77	.88	.90	.90	.93	.91	.95	.94	.98	1.00	.91	.91
$f\frac{3}{1}$:	.67	.48	.70	.70	.68	.71	.72	.74	.75	.67	.81	.69
$f\frac{\text{Sh.}}{1}$:	.52	.43	.63	.63	.64	.66	.69	.70	.74	.67	.74	.64

The average improvement for all ages of the second trial over the first amounts to 25%; of the third over the second, 8%; of the shortest (Sh.) over the third, 9%; of the third over the first, 31%; and of the shortest (Sh.) over the first, 36%. The clinic cases consistently improved more than the school cases in every index. The difference amounts to the following in each index (based on the figures above for the school cases): $f\frac{2}{1}$, .09; $f\frac{3}{2}$, .02; $f\frac{\text{Sh.}}{3}$, .03; $f\frac{3}{1}$ .10; and $f\frac{\text{Sh.}}{1}$, .11. The difference amounts to about 10%, based on the first and last two indices.

The effect of repetition is appreciably and consistently greater for the five lower than for the five higher B.-S. ages, as shown by the following tabulation:

B.-S. Ages:	$f\frac{2}{1}$	$f\frac{3}{2}$	$f\frac{\text{Sh.}}{3}$	$f\frac{3}{1}$	$f\frac{\text{Sh.}}{1}$
III to VII:	.71	.89	.87	.64	.57
IX to XIII:	.78	.94	.95	.73	.70
Difference:	.07	.05	.08	.09	.13

The difference between the initial and the best records $(f\frac{\text{Sh.}}{\text{I}})$ is very considerable. The improvement amounts to 43% for the low grade cases, but only 30% for the high grade cases. In other words, the less intelligent cases adjust themselves very poorly at first, and therefore improve relatively more than the high grade cases, who function more nearly at their best from the start. We have already seen that younger children improve more on their initial records than older children. Of course, the factor of chronological age complicates the B.-S. age classification, and explains, in part, the differences which we find between the lower and higher B.-S. ages. That is, the average chronological age increases, though not with absolute regularity, as the B.-S. age increases, as may readily be seen from an examination of the tables (XVI to XXVII). Indeed, the average chronological age for B.-S. ages II to VII is 9.0, whereas for ages IX to XIII, it is 13.7. The cases (largely subnormal) who are mentally younger are also, in the main, chronologically younger, and hence they should follow the same rule as young children in relation to older children.

The average time in seconds for each successive trial for the whole group of cases (all the individuals in all the ages) is as follows:

Trial:	I	II	III	Sh.
Averages:	35.0	26.8	23.5	22.1

It is of interest to compare these averages with the corresponding averages for the school cases (p. 76). The school group reacted decidedly more rapidly in all trials, the difference amounting to the following for each trial: 14.2, 9.3, 6.9 and 6.4 sec. The slower reaction rate of the clinic cases is due, no doubt, to the preponderance of subnormal cases in that group (ranging all the way from idiots to merely retarded cases). Somewhat less than 12 per cent of the school cases were classified as dull (only a very few of these being actually feeble-minded), 12% as bright and 75% as normal (average). On the other hand eighty-five and eight tenths per cent of the clinic cases were classed as subnormal (including 6 groups below normal), but only 10% as normal and 4% as supernormal (bright).

The difference between I and II for the clinic cases amounts to 8.2; between II and III, 3.3; between III and Sh., 1.4; between I and III, 11.5; and between I and Sh., or between the slowest and the shortest, 12.9 sec. These differences are more than 2½ times as large as the corresponding differences for the school group (p. 74). The indices of improvement, based on the above general averages are as follows:

$f\frac{2}{1}$	$f\frac{3}{2}$	$f\frac{\text{Sh.}}{3}$	$f\frac{3}{1}$	$f\frac{\text{Sh.}}{1}$
.76	.87	.94	.67	.63

These indices are, again, decidedly larger than the corresponding indices for the school group, the differences for the indices in the order given above being .08, .07, .00, .12 and .12. The reason that the clinic cases improved more than the school cases is due, again, to the much larger number of subnormal cases in the clinic group. The normal or bright child adjusts himself well to a new situation from the very beginning, hence he cannot improve as much upon his initial record as the retarded child who makes a poor initial adjustment. The conclusion (p. 53) can be verified by averaging together the records in each trial for all the different classifications of intelligence irrespective of the B.-S. or chronological age in which the subjects grade. The following tabulation gives the general averages for each intelligence classification for each trial, together with the indices of improvement:

	I	II	III	Sh.	$f\frac{2}{1}$	$f\frac{3}{2}$	$f\frac{\text{Sh.}}{3}$	$f\frac{3}{1}$	$f\frac{\text{Sh.}}{1}$
Imbeciles:	78.5	38.9	45.5	39.5	.49	1.17	.86	.58	.50
Morons:	34.4	25.5	22.7	21.4	.74	.89	.94	.66	.62
Border-line:	24.9	20.6	19.0	18.3	.82	.92	.96	.76	.73
Backward:	28.8	21.4	20.2	12.2	.74	.94	.95	.70	.66
Retarded:	27.7	23.0	20.9	19.4	.86	.90	.92	.75	.70
Normal:	29.6	24.0	22.2	19.3	.81	.92	.86	.75	.65
Bright:	24.8	23.3	22.7	22.4	.93	.97	.98	.91	.90

While there are exceptions it is seen that the lowest groups gain more than the highest. The average amount of gain for the three lowest groups, based on the last index $(f\frac{\text{Sh.}}{1})$, is 38.3%, while the average gain for the three highest groups is only 25%. The improvement is most marked for the imbeciles and morons. The large improvement for the normal cases is probably due to the preponderance of young children in this grouping. Actually the average age of the normal boys and girls was 8.78 and 8.65 years, respectively, while the corresponding ages of the imbeciles were 10.3 and 11.5, and of the morons 13.3 and 13.7. The retarded and backward children likewise averaged older than the normal pupils (cf. p. 67).

Clinic cases, arranged according to chronological age

The results will be analyzed only for "all grades," both sexes combined, ages 3 to 33, last four columns in Tables XXVIII to XLVII.

Ninety-five per cent of the fastest records were made during the third trial and the other 5% during the first; the same ratios of intermediate records were made during the second and third trials, while all the slowest reactions were made during the first trial. The gain from repetition is rather more marked in the chronological than in the B.-S. classification of the clinic cases.

The amount of improvement in terms of seconds between the fastest and the slowest reaction rates made during the three trials is as follows for each chronological age:

Chron. age:	3	4	5	6	7	8	9	10	11	12	13	14
Gain:	11.9	21.2	21.1	23.1	30.1	15.7	8.7	8.3	12.5	8.5	9.5	8.

Chron. age:	15	16	17	18	19	25	33
Gain:	9.7	5.2	5.7	5.	7.8	7.2	8.2

The average improvement for all ages, 17.6 sec., is 2.1 sec. larger than the corresponding average in the B.-S. classification. The improvement decreases with increasing chronological age, but less regularly than was the case in the B.-S. classification (p. 80). It is about 4 times as large in the group of 9 lower ages (3 to 11, 28.8 sec.) as in the group of 9 upper ages (12 to 33, 7.3 sec.). Here the difference between the lower and higher group of ages is slightly less than in the B.-S. classification.

The following tabulation gives each index of improvement in all the ages:

Chron. ages	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	25	33	Ave.
	1.60	.94	.76	.82	.68	.68	.71	.91	.69	.78	.72	.73	.67	.76	.81	.79	.97	.82	.99	.83
	.29	.75	.87	.72	.75	.93	.97	.79	.93	.90	.92	.90	.93	1.06	.95	.94	.66	.79	.69	.82
	1.00	.92	.98	.97	.95	.95	.89	.95	.93	.93	.91	.96	.93	.86	.87	.99	1.00	1.00	1.00	.94
	.47	.70	.66	.59	.51	.64	.73	.72	.65	.71	.67	.67	.65	.84	.77	.75	.64	.60	.68	.66
	.47	.66	.66	.57	.48	.61	.65	.69	.60	.66	.62	.64	.61	.70	.68	.74	.64	.60	.68	.63

The average gain in all ages of the second trial over the first amounts to 17%; of the third over the second, 18%; of the shortest (Sh.) over the third, 6%; of the third over the first, 34%; and of the shortest (Sh.) over the first, 37%. Compared with the B.-S. classification, the improvement is decidedly less (by 8%) in the first index ($\frac{2}{1}$), and decidedly greater (by 10%) in the second ($\frac{3}{2}$). The reason for this discrepancy is not clear, although it is partly accounted for by the abnormal figures in age 3. If age 3 is eliminated the gain of two over one is increased to 21% ($f\frac{2}{1} = .79$), and the gain of three over two is decreased to 15% ($f\frac{3}{2} = .85$). The greatest gains are thus in $f\frac{2}{1}$, $f\frac{3}{1}$ and $f\frac{\text{Sh.}}{1}$ in both the chronological and B.-S. classifications.

The 9 younger ages show more improvement from repetition than the 9 older ages, as shown by the following indices:

Chron. ages:	$f\frac{2}{1}$	$f\frac{3}{2}$	$f\frac{\text{Sh.}}{3}$	$f\frac{3}{1}$	$f\frac{\text{Sh.}}{1}$
3 to 11:	.87	.77	.94	.63	.59
12 to 33:	.80	.87	.94	.69	.65
Difference:	—.07	.10	.00	.06	.06

The exception in $f\frac{2}{1}$ disappears if the abnormal figure in age 3 is eliminated, which gives an index of .78 instead of .87 and a difference of .02 (and an index of .84 in $f\frac{3}{2}$ instead of .77, and a difference of .03). The differences, however, are smaller than the corresponding differences between the lower and higher B.-S. ages (p. 81). The reason for this may be the fact that not so large a percentage of the cases in the lower chronological ages were subnormal and a larger percentage were normal or bright than in the upper chronological ages. Thus the greater normal gain made by the young and retarded cases, in the lower ages, would be partly offset by the presence of bright children, who gain less because of their effective initial attack. On the other hand, a larger preponderance of subnormal children in the older chronological ages, or a deeper degree of average retardation in the older group, would tend to cause a larger improvement from repetition. The reason that the older children do not improve absolutely more than the younger cases is the fact that they are chronologically older—the accelerated improvement from repetition which goes with backwardness is partly offset by the diminished improvement from repetition which goes with greater maturity.

General Results and Conclusions

1. There is a constant and marked gain in efficiency with each repetition in this test. This gain is evident in all the groups of cases. In the vast majority of instances, the poorest averages come in the first trial, the intermediate averages in the second, and the best averages in the third trial (of course, there are numerous individual exceptions).

2. The amount of the gain between the slowest and fastest averages is very considerable. It amounts to 5.1 sec. for the normal (school) cases, based on the general averages for all the cases, 15.5 sec. for the clinic cases, B.-S. classification, and 17.6 sec. for the clinic cases, chronological classification. The normal children gained 25% over their slowest records, while the clinic cases gained 36% (B.-S. classification) and 37% (chronological classification). The improvement from repetition is distinctly larger, both absolutely and relatively, for the subnormal cases. This is true for every index of improvement.

3. The reason that the subnormal cases improve more than

the normal cases is due to the fact that the normal cases are capable of making an effective initial adjustment while the subnormal cases are more or less confused at first by the complexity of the problem. Because they make a poor initial attack they are able to show a larger relative gain in the later trials. That the amount of improvement resulting from repetition is a function of the degree of intelligence of the child is further indicated by the considerations advanced in the four following paragraphs.

4. The lower grades of subnormal children gain relatively more from repetition than the higher grades. The gain of the Sh. averages over the averages in the first trial amounts to 38.3% for the imbeciles, morons and border-line cases, but only 25% for the retarded, normal and bright cases.

5. The younger children gain more from repetition than the older children. This is not only true for the normal children, but also for the subnormal whether classified according to chronological or B.-S. age (the children in the lower B.-S. ages average younger than those in the upper B.-S. ages). But the difference is larger in the subnormal group than in the normal group. The difference between the indices for the younger and older normal cases amounts to over .10. The younger children are, of course, less intelligent than the older children, hence make a poorer initial attack.

6. Among the normal children the dull pupils gain slightly more than the bright pupils. However, the average pupils gain more than either the bright or the dull—possibly for the reason advanced on page 77.

7. Young bright children compared with older bright children improve relatively less than young dull children compared with older dull children, probably for the reasons given on page 80. The latter improve relatively about twice as much.

8. The improvement made from the first repetition is relatively much greater than the improvement made from the second repetition; that is, the difference between the first and second trials is greater than the difference between the second and third trials. This is true both for the normal and the subnormal cases. Thus for normal children the improvement in the IId trial, based

on the general average for all cases, amounts to 16% compared with 6% in the IIId trial (*i. e.*, the IIId compared with the IId trial); and for the subnormal cases, B.-S. classification, the corresponding figures are 25% and 8%. The amount of improvement of the shortest (Sh.) averages over the IIId trial is about the same as the IIId over the IId for both the normal and the subnormal cases (except that it is smaller in the chronological classification of the subnormal cases). This indicates that the most satisfactory criterion by which to compare the efficiency of different types or grades of individuals in this test, as it is usually conducted, is the shortest score of the three trials. At the same time, from all the evidence at hand it is quite clear that the children would continue to increase in efficiency in successive trials after the third trial. But the absolute amount of increment, manifestly, would decrease from test to test.

9. The facts which we have discovered regarding the practice differences in the form-board test between dull, bright and average, and younger and older, children offer a means of explanation of the discrepancies sometimes found between the results of different investigations on the curves of learning, practice, fatigue, recuperation. A curve which may apply to one grade or one age of intelligence need not necessarily apply to a different grade of intelligence. Curves of improvement based on the work of bright college students might have more or less application to bright children, but little or no application to dull children. Similarly curves of fatigue may differ according as they are based on the work of bright, average or dull pupils in the grades, or of bright mature students in the university.

CHAPTER VI

VARIABILITY IN PSYCHO-MOTOR PERFORMANCE

The M.V. (or A.D.) furnishes a measure (although less accurate than the S.D.) of the amount of deviation or variability between the individual measurements of a given series of measurements. It enables us to determine the difference in variability with respect to any trait between different subjects in different chronological or B.-S. ages, between different types of cases (bright, normal, dull, feeble-minded, epileptic, insane), between the two sexes, between children and adults, etc. It also enables us to determine the reliability of any given age-norms, for it is evident that if the variation between the trait scores of children of the same age is very large the norms have little or no value. The larger the variability between the individual measures the less do the means represent central tendencies.

The absolute M.V.'s in the tables have been worked out separately for the boys and the girls. That is, the M.V.'s for the boys of any given age represent the average of all the differences between each determination and the mean value in the boys' series of measurements and similarly for the girls. On the other hand, the M.V.'s for "both sexes" (owing to inability to find time for the more extended calculation) have been computed by adding the M.V.'s for the boys and girls of the same age and dividing by two. As is well known, the average so obtained is not absolutely accurate. While the difference between the averages obtained by the abbreviated and complete method may sometimes be quite appreciable, I have not found, in any of the cases in which I have proved the results, that the differences are sufficiently large to modify the general conclusions drawn. However, if the reader demands precisely accurate figures he may confine his attention to the M.V's. and coefficients given separately for the boys and the girls.

The relative M.V. or coefficient of variability, in distinction from the absolute M.V., expresses the M.V. in relation to the average $(\frac{\text{M.V.}}{\text{Ave.}})$. It is a more significant measure, because it gives the size of the deviation in relation to the size of the average. A deviation of 2 is important when the average is 10, but insignificant when the average is 100.

The school cases

The average M.V. for both sexes, based on the averages of the shortest records (Sh.) for all the whole-year ages, 4 to 15, inclusive, amounts to 1.9 sec. per year. Since this is 12% of the average time of these records for all the pupils, it indicates that there is a moderate amount of variability in form-board performance among children of the same age who differ in intelligence not more than children selected from a normal distribution (an unselected array of normal children).

The absolute M.V. decreases regularly from trial to trial, as indicated by the following averages for ages 4 to 15: I, 3.3 sec.; II, 2.8; III, 2.4 sec.; and Sh., 1.9 sec. The M.V.'s decrease in 78% (39) of the comparisons from trial to trial, in only 4% (2) of the trials are they the same and in only 18% (9 instances) do they increase in successive trials. The index of variability also decreases somewhat for the third trial and for the shortest scores but not in the second trial: I, 15%; II, 16%; III, 14%; and Sh., 12%. It is evident that, from the standpoint of variability, we are justified in using the shortest records in preference to I, II or III.

The absolute M.V. is very slightly smaller for the boys than for the girls, except in the second trial, as indicated by the following M.V.'s for ages 4 to 15, inclusive:

Trial:	I	II	III	Sh.
Boys:	3.8 sec.	2.9 sec.	2.2 sec.	1.7 sec.
Girls:	4.8	2.8	2.7	2.0

The biggest difference is in the first trial, 1 sec. The boys' M.V. is smaller than the girls' in 66% of the ages in the first trial (larger and equal in 16% each), in 50% in the second trial, in 42% in the third trial, and in 58% for the shortest scores (larger in 33% and equal in 8%).

The coefficient of variability is likewise smaller for the boys except in the second trial, as shown by the following $\frac{\text{M.V.'s}}{\text{Ave.}}$ for ages 4 to 15, inclusive:

Trial	I	II	III	Sh.
Boys:	18%	16%	13%	10%
Girls:	21%	15%	15%	12%

In the following tabulation the coefficient of variability, based on the shortest scores (Sh.) is given separately for the boys and the girls for each chronological age from 4 to 15:

Ages:	4	5	6	7	8	9	10	11	12	13	14	15	Ave.
Boys:	.13	.09	.11	.14	.10	.09	.09	.10	.09	.11	.09	.07	.10
Girls:	.11	.11	.13	.13	.07	.12	.08	.10	.07	.11	.07	.09	.099

While the coefficient is less for the girls in six of the ages, greater in four ages and equal to the boys in two ages, the average coefficient for all the ages is practically the same.

There is a decrease in the size of the coefficients in 6 of the successive ascending ages, an increase in 4 and equal coefficients occur once in the case of the boys; and a decrease in 5 ascending ages, an increase in 4 ages and equal coefficients occur twice in the case of the girls.

The absolute M.V. decreases fairly regularly from age to age. In the first and second trials there is a decrease in 73% of the ages (4 to 15, both sexes combined), and an increase in 27%; in the third trial an increase and decrease each in 45%, and equal scores in 9% of the ages; and in the averages for the shortest scores a decrease in 54%, an increase in 36%, and equal scores in 9% of the ages. In the following tabulation the average M.V.'s are given for both sexes only for the age-groups indicated:

Trial:	I	II	III	Sh.
Ages 4-7:	5.8 sec.	4.7 sec.	3.6 sec.	3.1 sec.
Ages 8-11:	2.6	2.5	1.9	1.4
Ages 12-15:	1.6	1.3	1.7	1.1

The decrease in the variability with ascending age groups is greatest in the first trial (amounting to 4.2 sec. between the lowest and highest groups), followed by the second trial (3.4 sec.). It is practically the same for the third trial and for the shortest scores (Sh.).

The clinic cases, arranged according to B.-S. age

The average M.V. for all cases, based on the averages of the shortest records (Sh.) for all the B.-S. ages (IV to XII), amounts to 4.6 sec. per B.-S. age, which is 20% of the average time required by all the pupils to replace the blocks. The absolute M.V. is 2½ times as large, while the coefficient of variability is not quite twice as large for the clinic as for the school group of cases.

The absolute M.V. decreases with each successive trial, as shown by the following figures for both sexes (averages for ages III to XII) for each trial: I, 13.5 sec.; II, 7.8 sec.; III, 5.7 sec.; and Sh., 4.6 sec. The M.V.'s decrease from trial to trial in 81.4% (22) of the comparisons, increase in 11.1% (3), and are equal in 7% (2) of the cases.

The coefficient of variability likewise decreases with each successive trial, as shown by the following figures: I, 38%; II, 29%; III, 24%; and Sh., 20%.

In all trials the absolute and relative M.V.'s are emphatically larger for the clinic (subnormal) than the school (normal) cases, as shown by the following figures which indicate the amount by which the M.V.'s for the clinic cases exceeds the M.V.'s for the school cases:

Trial:	I	II	III	Sh.
M. V.	10.0 sec.	5.0 sec.	3.3 sec.	2.7 sec.
$\frac{\text{M. V.}}{\text{Ave.}}$	23%	13%	10%	8%

The variability for the clinic case, relative to the school case, is most pronounced in the first two trials, particularly the first. In the first trial the difference in the variability between the clinic and the school cases is about twice as great as in the second trial. As was the case with the normal children the variability is least for the averages of the shortest scores showing, again, that the best single index for the form-board performance is the average of the shortest scores.

The absolute M.V. is smaller for the girls than for the boys in the first three trials and larger for the averages of the shortest scores (Sh.), as shown by the following average M.V.'s for ages IV to XII:

Trial:	I	II	III	Sh.
Boys:	14.1 sec.	8.3 sec.	5.7 sec.	4.1 sec.
Girls:	12.8	7.4	5.6	5.0

The largest difference between the two sexes, in the first trial, amounts to only 1.3 sec.

The following tabulation gives the average M.V.'s for the lower (IV to VII) and higher (VIII to XII) B.-S. ages for the two sexes in each trial:

	Lower ages				Upper ages			
Trial:	I	II	III	Sh.	I	II	III	Sh.
Boys:	26.6	15.1	9.5	6.9	4.2	2.9	2.7	2.0
Girls:	23.2	13.2	9.4	8.7	4.4	2.9	2.5	2.1

The M.V.'s are from 3 to 6 times as small in the upper as in the lower group of ages. The M.V.'s are smaller for the girls in the lower ages in all trials except the Sh., but in the upper ages in the third trial only, being equal in the second trial, and larger in the first and Sh.

The girls' M.V.'s are smaller than the boys' in 55% of the B.-S. ages in the first trial (larger than the boys in 33%, and equal in 11%); in 77% of the ages in the second trial (larger in 22%); in 66% of the third trial (larger in 33%); and in 44% of the ages in the averages for the shortest scores (larger in 44% and equal in 11%).

On the whole, the absolute variation is somewhat less for the subnormal girls than for the subnormal boys, while the reverse was the case for the normal cases. The coefficient of variability, however, is smaller for the girls only in the first two trials, and larger in the third trial and for the shortest averages, as indicated by the following average coefficients for ages IV to XII:

Trial:	I	II	III	Sh.
Boys:	.41	.32	.24	.18
Girls:	.36	.28	.25	.23

The maximal superiority of the one sex over the other is the same for the boys and the girls, .05.

The absolute M.V. usually decreases with each ascending B.-S. age. In the first trial there is a decrease in 75% of the ages (IV to XII, both sexes combined), an increase in 12%, while the variation is the same in 12%. In all the other trials there is a decrease in 75% and an increase in 25% of the ages.

The following are the average absolute M.V.'s for the age-groups indicated, based on the averages for both sexes:

Trials:	I	II	III	Sh.
Ages IV-VII:	24.9 sec.	14.1 sec.	9.4 sec.	7.7 sec.
Ages VIII-XII:	13.5	7.8	5.7	4.6

As was the case with the normal children, the decrease in absolute variability is greatest in the first trial (11.4 sec.), followed by the second (6.3 sec.); and it is about the same in the third trial as for the shortest scores (3.7 vs. 3.3 sec.). The gain in absolute regularity with ascending age-groups is considerably greater for the clinic than for the school cases.

The following tabulation contains the coefficients of variability, based on the M.V.'s for the shortest scores (Sh.), for the boys and girls for B.-S. ages IV to XII:

Ages:	IV	V	VI	VII	VIII	IX	X	XI	XII	Ave.
Boys:	.15	.19	.25	.16	.22	.12	.14	.06	.007	.14
Girls:	.31	.28	.16	.15	.20	.08	.10	.10	.15	.17

The coefficients decrease with ascending B.-S. ages in half of the ages, and increase in half for the boys, and decrease in 50%, increase in 37% and are equal in 12% of the ages for girls. However, the average coefficient for the lower ages (IV to VII) is considerably greater for both the boys and the girls than the average coefficient for the upper ages (VIII to XII), the difference amounting to .10 for the boys (.18 vs. .08) and .15 for the girls (.25 vs. .10). The girls' variability is less than the boys' in 5 ages and greater in 4 ages, but the average coefficient for all ages, as well as for the lower and upper groups of ages, is somewhat larger for the girls. For ages IV to VII it is larger by .07 (.25 vs. .18) and for ages VIII to XII by .02 (.10 vs. .08).

Clinic cases, arranged according to chronological age

The average M.V. for the shortest scores (Sh.) for both sexes for ages 6 to 16 amounts to 3.4 sec., which is 15% of the average time required to replace the blocks by all the children included. The absolute M.V. is 1 sec. less, while the coefficient is 5% less when the clinic cases are grouped chronologically than when they are grouped by mental ages. It must be remembered, however, that the cases compared do not exactly correspond, as the redistribution by chronological ages made it impossible to include a number of cases because of lack of comparative data in some ages.

The absolute M.V. decreases with each successive trial, as shown by the following figures for both sexes combined for each trial, based on the averages for ages 6 to 16: I, 8.8 sec.; II, 4.6 sec.; III, 4.3 sec.; and Sh. 3.4 sec. The M.V.'s decrease from trial to trial in 82% (27) of the comparisons, and increase in 18% (6), based on the averages for both sexes.

The coefficient of variability likewise decreases from trial to trial, except that it is slightly larger in the third than in the second trial, as shown by the following figures: I, 25%; II, 17%; III, 18%; and Sh., 15%. It is to be observed, again, that these coefficients are smaller in each trial than the coefficients for the B.-S. classification of the clinic cases, and that the greatest relative decrease in variability occurs in the second trial in both classifications.

The absolute M.V.'s are smaller in all trials for the girls than for the boys, as shown by the following average M.V.'s for ages 6 to 16:

Trial:	I	II	III	Sh.
Boys:	9.7 sec.	5.5 sec.	5.6 sec.	3.9 sec.
Girls:	7.0	3.7	3.1	3.0

The largest difference between the sexes amounts to 2.7 sec. in the first and the smallest .9 sec. in the averages for the Sh. records.

The corresponding figures for the five lower ages (6 to 10) and five higher ages (12 to 16) are as follows:

	Lower ages				Upper ages			
Trial:	I	II	III	Sh.	I	II	III	Sh.
Boys:	11.4	6.9	7.7	3.9	8.4	4.0	2.6	3.3
Girls:	12.1	4.9	4.1	4.1	3.3	2.2	2.1	2.0

In the lower age-group the girls excel in two trials, and in the upper age-group in all the trials.

The girls' M.V.'s are smaller than the boys' in the first trial in 63% and larger in 36% of the ages compared (6 to 16); smaller in 90% of the ages in the second trial, and larger in 9%;

smaller in 72% in the third trial and larger in 27%; and smaller in 63% for the averages for the shortest scores and larger in 36%. It is thus apparent that, all in all, the absolute M.V. is smaller for the clinic girls than for the clinic boys in both the chronological and B.-S. groupings, and that relatively the girls' M.V. is smaller in the chronological than in the B.-S. classification.

The coefficients of variability (based on the averages for ages 6 to 16) are smaller for the girls in all trials, as shown by the following average coefficients for ages 6 to 16:

Trial:	I	II	III	Sh.
Boys:	.28	.20	.23	.17
Girls:	.19	.14	.14	.14

The girls' variability, unlike the boys', does not decrease after the second trial. The maximal difference in any one trial between the boys and the girls amounts to .09. The girls' coefficient is distinctly less than the boys' when the cases are chronologically classified but not when they are classified according to B.-S. age. The girls' coefficient in the B.-S. series is sometimes smaller and sometimes larger than the boys'.

The absolute M.V. does not decrease so regularly with each ascending chronological age as with each ascending B.-S. age. In the first trial it decreases in 70% and increases in 30% of the ages compared (IV to XII, both sexes combined); in the second trial, it decreases in 60%, increases in 30% and is equal in 10% of the ages; in the third trial it decreases in half and increases in half of the ages; and in the averages for the shortest scores it decreases in 60% and increases in 40% of the ages.

In the following tabulation is given the average M.V.'s for the age-groups indicated, based on the combined averages for the two sexes:

Trials:	I	II	III	Sh.
Ages 6-10:	11.7 sec.	5.8 sec.	5.0 sec.	4.0 sec.
Ages 12-16:	5.8	3.3	3.2	2.6

Uniformly the M.V.'s are smaller in the upper ages, the decrease being greatest in the first (5.9 sec.) and second (2.5 sec.) trials, as was the case for the normal children and the subnormals classified by mental age. The improvement in the absolute regularity of the clinic cases between the lower and the upper groups is about twice as large for each B.-S. age as for each chronological age.

The coefficients of variability, based on the M.V.'s for the shortest scores (Sh.), are as follows for the boys and girls for ages 6 to 16:

Ages:	6	7	8	9	10	11	12	13	14	15	16	Ave.
Boys:	.11	.15	.12	.23	.09	.31	.22	.25	.11	.14	.12	.14
Girls:	.04	.20	.21	.18	.16	.10	.08	.24	.07	.15	.03	.11

The coefficient decreases with ascending age in half of the ages for the boys and increases in half, while it decreases in 60% and increases in 40% of the ages for the girls. The average coefficient for the lower ages (6 to 10) is less than for the upper ages (12 to 16) for the boys (.14 compared with .16), but larger for the girls (.15 vs. .11). It is evident that the coefficient does not diminish in the older chronological group as it did in the higher B.-S. group of ages—due, presumably, to the presence of low-grade subjects in the older chronological ages.

The girls' coefficients are less than the boys in 7 ages and greater in four. The girls' average coefficient is likewise less for the four upper ages (.11 vs. .16 for the boys), and for the averages of all the ages from 6 to 16 (.11 vs. .14), but not for the four lower ages (.15 vs. .14 for the boys).

General Results and Conclusions

1. The variability in form-board performance is considerably greater for subnormal cases when classified either according to chronological or B.-S. age, than for normal children when classified according to chronological age. The average variation for the latter, based on the Sh. scores, whole-year classification for all cases, amounts to 1.9 sec. (M.V.), which is 12% of the average. The M.V., based on the Sh. scores, is about 2½ times greater and the coefficient not quite 2 times greater for the subnormal cases, B.-S. classification. While the statement has usually been accepted that subnormal subjects rank higher in "motor" than in mental age, it is seen that this is by no means uniformly the case. The large variability indicates that some

do very well in the form-board tests, while others do very poorly. In this test the subnormals differ among themselves in each mental or chronological age decidedly more than the normal children vary in each chronological age. Possibly this is partly accounted for by the greater range of chronological ages among the subnormal cases.

The absolute and relative variability is decidedly larger for epileptics than for our normal or subnormal cases, as shown by the following figures, reproduced from our earlier study[1]:

	M. V.	M. V. Ave.
Epileptic boys	14.6	.27
Epileptic girls:	34.9	.47
Epileptic men:	19.7	.39
Epileptic women:	14.0	.25
All epileptics:	24.8	.24

Of all the classes which we have studied by means of the form-board, the epileptics are the most variable (the data for the epileptics were tabulated according to B.-S. age only).

Both the absolute and relative variability are perceptibly less in the chronological than in the B.-S. classification of the clinic cases. This may be due to the fact that the number of cases does not precisely correspond, as some cases could not be included in the chronolgical classification. It would otherwise seem to indicate that the responses are less variable when subnormal cases are classified by chronological than by B.-S. age, and this would mean that uniformity in form-board performance between subnormal cases is more dependent upon equality of chronological age than upon equality of mental development —a conclusion not quite in accordance with expectation.

2. There is a steady and fairly continuous decrease (occurring in 78% of the comparisons) in absolute variability from trial to trial with the normal cases. There is also a slight decrease in the coefficient, except in the second trial. The decrease is emphatically larger for the subnormal cases, particularly when classified according to B.-S. age. The difference between the subnormal cases (B.-S.) and the normal cases is almost twice as large in the first trial (23%) as in the second trial (13%). The

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[1] Experimental Studies of Mental Defectives, pp. 74 and 96.

subnormal cases are distinctly more variable during the first trial, and they make the largest relative amount of improvement in the second trial, while the normal cases are no more variable $(\frac{M.V.}{Ave.})$ in the first than the second trial. This shows that the subnormal individuals are least dependable in their initial performance, while the normal individuals are almost as constant in their first performance as in their second or third.

Both the absolute and relative variabilities are consistently smaller in all trials in the chronological than in the B.-S. classification of the subnormal cases.

3. The smallest absolute, as well as relative, variability occurs in the averages for the Sh. scores for both the normal and the subnormal cases. From the standpoint of variability the best standard by which to gauge the relative psycho-motor efficiency of different subjects is the best record of the three. Facts drawn from different considerations have already been given to justify this conclusion (pp. 71, 88).

4. The variability decreases with increasing chronological and mental age; the more mature and intelligent individuals function more regularly than the less mature or intelligent, particularly so far as concerns subnormal cases and particularly so far as concerns the first or second trials. These conclusions are indicated by the following facts.

The M.V. is found to decrease fairly constantly with each ascending age for both the normal and subnormal cases. But the decrease occurs less frequently in the chronological than in the B.-S. classification of the subnormal cases. While the decrease is more frequently apparent in the first two trials than in the third or Sh. scores for the normal cases, this is not the case for the subnormal cases (B.-S. classification).

The coefficients $(\frac{M.V.}{Ave.})$ likewise tend to decrease very slightly more frequently with ascending ages for the normal cases but not for the subnormal (the increase is just as frequent as the decrease in the B.-S. classification).

When the results are averaged for the lower and higher age-groups, the M.V.'s are uniformly smaller in the higher than in the lower groups for both the normal and the subnormal cases, both classifications. Here, again, the decrease is decidedly larger for the subnormal than the normal cases, and larger in the B.-S. than the chronological classification of the subnormals. The greatest decrease occurs in the first and second trials for both the normal cases and subnormal cases, both classifications. The coefficient of variability is decidedly smaller in the upper than in the lower group of ages in the B.-S. classification, but not in the chronological classification of the subnormal cases. In the latter it is slightly larger in the upper ages for the girls but slightly smaller for the boys.

5. The data are not very conclusive on the question as to whether the variability is greater for the boys or for the girls.

Among the normal cases the size of the M.V. is slightly smaller for the boys in all the trials except the second. The M.V. is smaller more frequently (in more ages) for the boys in the first trial and in the Sh. scores, it is smaller for the girls in the third trial, while it is equal for both sexes in the second trial. The coefficient is likewise smaller for the boys except in the second trial. However, when based on the Sh. scores, the coefficient is smaller for the girls than for the boys in 6 ages, larger in 4 ages and equal in 2 ages. The average coefficient for all ages is about the same for both sexes.

In the chronological classification of the clinic cases the M.V. is smaller for the girls than for the boys in all trials (maximal difference 2.7 sec.). It is likewise smaller for the girls in the upper group of ages in all trials, but only in two trials in the lower group of ages. The coefficient is also smaller for the girls in all trials in all ages (maximal difference, .09). Based on the Sh. trial, the amount by which the girls excel the boys amounts to .03 (.14 — .11), the girls' variability being less than the boys' in 7 ages and greater in 4.

In the B.-S. classification of the subnormal cases the size of the M.V.'s is smaller for the girls in I, II and III, but not in the Sh. column (maximal difference between the boys and the girls, 1.3 sec.). In the lower ages it is likewise smaller for the girls in all trials, with one negligible exception, while in the upper ages it is smaller for the girls in the third trial only, being equal in the second trial, and larger in the first and the Sh. scores. The M.V. is more frequently (in more ages) smaller for the girls in the first, second and third trials, but not in the Sh. scores. The coefficient is smaller for the girls in I and II, but for the boys in III and Sh. (maximal difference .05). But based on the averages for the lower and upper group of ages, it is slightly larger for the girls. These results would not justify more than the tentative statement that the variability tends to be slightly larger for subnormal boys than for subnormal girls, and slightly smaller for normal boys than normal girls.

I may here tabulate the results of a study of the comparative coefficients of variability in tests given to subnormal epileptic males and females.[2]

The coefficients of variability are greater for the girls than for the boys in the following tests: naming four colors (a difference of .10); naming 60 words in three minutes (difference, .10); memory of selection read (difference, .09); form-board performance (difference, .20); and hand dynamometry, right hand (difference, .01).

In the following test the coefficient is larger for the boys than for the girls: reading test (difference, .03).

In the following test the coefficient is larger for the women[3] than for the men: dynamometry, right hand (difference, .03).

In the following tests the coefficients are larger for the men than for the women: 60-word test (difference, .11); four colors (difference, .18); reading (difference, .03); and form-board test (difference, .14). In the memory test, however, the coefficients are the same.

In ataxiagraphic sway the coefficients are greater for the males than the females in the antero-posterior direction, eyes shut (difference, .06); and greater for the females than the males in the lateral direction, eyes shut (difference, .01) and eyes fixated

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[2] Experimental Studies of Mental Defectives, 93ff.

[3] The sense in which the words boys, girls, men, women, males and females are used is given on p. 65.

(difference, .06), and in the antero-posterior direction, eyes fixated (difference, .10).

Here we find the curious result that whereas the coefficients are larger in five tests for the girls and in only one test for the boys, they are larger in four tests for the men and in only one test for the women. That the evidence is just as inconclusive from the study of variability in the epileptic as in the feeble-minded or normal is indicated, further, by the following facts: the average of the per cents of passes for the individual tests in each of the B.-S. ages in which the subjects were classified was exactly the same for the boys as for the girls (61%); and the average M.V. for all ages (except XIII) between the per cents of passes for each test in each age was approximately the same for boys as for girls (.20 vs. .21).[4] However, the range between the highest and the lowest per cent of passes for the tests in each age was larger for the girls (.74%) than for the boys (60%).[5]

It is evident that the only conclusion which seems clearly justified by a careful analysis of variability in different types of abnormal and normal subjects is that in some tests the male se is less variable, in others the female sex is less variable, wh in still others there is practically no difference. We have fo no experimental warrant for the sweeping statement that t male sex represents variation and the female sex conservation.

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[4] As before, p. 34.
[5] As before, p. 39.

6½ years $(6^4\text{-}6^9)$

Bright

Bellefield	3	29.6	6.9	25.2	0.9	19.9	0.7	19.9	0.7										3	29.6	25.2	19.9	19.9
Colfax	1	29.0		26.5		23.2		23.2		5	26.1	4.02	26.1	2.9	23.2	4.6	23.2	2.88	6	26.6	26.2	23.2	23.2
Ave.	4	29.4		25.5		20.7		20.7											9	27.6	25.7	22.1	22.1
											Average												
Bellefield	10	28.6	5.9	25.2	4.1	22.3	2.8	21.78	2.8	6	24.7	3.16	22.8	2.8	22.4	3.1	21.0	2.2	16	27.1	24.3	22.3	21.5
Sch. of Ch.	2	37.5	10.9	22.5	1.7	23.5	3.5	22.1	2.1										2	37.5	22.5	23.5	22.1
Holmes	22	32.5	7.4	23.8	1.8	22.9	3.5	22.0	3.6	8	34.1	7.8	25.1	3.6	48.3	3.1	22.3	2.9	30	33.0	24.2	29.7	22.0
Ave.	34	31.7	8.0	24.1	2.5	22.8	3.2	21.9	2.8	14	30.1		24.1	3.2	37.2	3.1	21.7	2.5	48	31.2	24.1	27.0	21.9
											Dull												
Bellefield	1	30.2		28.0		24.0		24.0											1	30.2	28.0	24.0	24.0
Holmes										1	62.0		47.6		31.0		31.0		1	62.0	47.6	31.0	31.0
Ave.																			2	46.1	37.8	27.5	27.5

6 years $(6^0\text{-}6^{11})$

Bright

Bellefield	4	28.1	5.9	23.0	3.2	18.7	1.8	18.7	1.8										4	28.1	23.0	18.7	18.7
Colfax	2	29.5	0.5	23.5	3.0	21.1	2.1	21.1	2.1	10	24.2	3.4	23.5	3.2	21.8	2.9	21.5	2.77	12	25.1	23.5	21.7	21.4
Ave.	6	28.5	3.2	23.2	3.1	19.5	1.9	19.5	1.9										16	25.8	23.4	20.9	20.7
											Average												
Bellefield	19	30.1	7.96	25.1	3.7	23.1	3.4	22.2	3.1	15	27.5	5.1	24.8	3.8	22.2	3.2	21.37	2.7	34	26.0	24.99	22.7	21.8
Sch. of Ch.	2	37.5	9.9	22.5	1.7	23.5	3.5	22.1	2.1	1	35.6		22.8		21.0		21.0		3	36.8	22.6	22.6	21.7
Holmes	35	33.2	7.6	23.8	3.4	22.7	3.3	21.96	3.3	20	35.1	8.3	26.3	5.5	23.9	3.7	23.3	3.5	55	33.9	24.8	23.2	22.4
Ave.	56	32.3	8.4	24.2	2.9	22.8	3.4	22.0	2.8	36	31.9	6.7	25.6	4.6	25.6	3.4	22.4	3.1	92	32.2	24.7	23.0	22.2
											Dull												
Bellefield	1	30.2		28.0		24.0		24.0											1	30.2	28.0	24.0	24.0
Holmes	1	26.0		20.2		22.2		20.2		3	50.2	13.6	37.2	6.9	26.0	3.2	26.0	.32	4	44.2	32.9	25.1	24.6
Ave.	2	28.1		24.1		23.1		22.1											5	41.4	31.9	24.8	24.4
Ave. Ae. 6		30.3	6.3	24.1	3.0	22.5	2.8	21.8	2.4		31.5	7.6	25.9	4.8	23.0	3.2	22.4	3.0		31.7	24.9	22.8	22.1

TABLE V

7 years $(6^{10}\text{-}7^8)$

Bright

School	Boys									Girls									Both Sexes				
		I		II		III		Sh.			I		II		III		Sh.			I	II	III	Sh.
	No.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	No.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	No.	Ave.	Ave.	Ave.	Ave.
Bellefield	3	23.2	5.1	17.7	2.2	16.7	2.1	16.7	2.1										3	23.2	17.7	16.7	16.7
Colfax	3	25.4	4.26	29.4	4.9	28.9	7.6	24.9	4.9	6	20.5	1.4	20.0	1.7	19.5	1.9	18.5	2.2	9	22.1	23.1	22.6	20.6

Ave.	6	24.3	4.0	23.5	3.5	27.3	4.0	20.7	3.5														
Average																							
Bellefield	7	25.8	4.4	20.1	1.9	18.8	1.8	18.37	1.8	8	30.1	6.58	26.1	3.4	22.4	3.38	22.4	3.38	15	28.1	23.3	20.7	20.5
Holmes	20	26.8	5.8	22.7	3.2	20.4	3.1	19.7	2.7	27	26.0	4.6	21.2	2.7	20.1	2.2	19.2	1.86	47	26.4	21.8	20.2	19.1
Ave.	27	26.6	5.1	22.0	2.5	20.0	2.4	19.3	2.2	35	26.9	5.5	22.3	3.0	20.6	2.7	19.9	2.5	62	26.8	22.2	20.3	19.6
Dull																							
Bellefield	2	23.3	1.9	21.5	2.5	19.5	0.5	19.5	0.5	1	27.0		21.0		21.0		21.0		3	24.5	21.3	20.0	20.0
Holmes	8	31.9	7.2	23.9	3.7	24.2	5.0	22.6	4.0	4	28.4	4.9	24.0	3.6	20.5	1.8	19.1	2.1	12	30.7	23.97	23.0	21.4
Ave.	10	30.2	8.1	23.4	3.1	23.2	2.7	22.0	2.2	5	28.1		23.4		20.6		19.4		15	29.5	23.4	22.4	21.1
7½ years (7^4-7^9)																							
Bright																							
Bellefield	2	16.5	2.5	16.0	1.0	15.8	2.8	15.0	2.0	1	16.6		16.4		20.0		16.4		3	16.5	16.1	17.2	15.5
Colfax	2	22.5	3.5	19.7	1.2	18.7	1.2	18.7	1.2	3	25.3	1.7	21.0	1.2	18.8	2.2	18.8	2.1	5	22.2	20.5	18.8	18.7
Ave.	4	19.5	3.0	17.8	1.1	17.2	2.0	16.8	1.6	4	23.1		19.9		19.1		18.2		8	21.3	18.8	18.2	17.5
Average																							
Bellefield	11	20.2	2.3	19.7	1.9	18.9	2.8	17.0	1.36	10	26.5	7.36	20.7	1.6	19.1	2.1	17.9	1.5	21	23.2	20.2	19.0	17.4
Holmes	20	26.0	5.2	19.3	2.8	20.7	4.0	18.6	2.66	17	27.3	4.4	20.0	2.6	20.1	2.9	18.7	2.47	37	26.6	19.6	20.4	18.6
Ave.	31	23.9	3.7	19.4	2.3	20.1	3.4	14.8	1.9	27	27.0	5.8	20.3	2.1	19.7	2.5	18.4	1.9	58	25.3	19.8	19.9	18.2
Dull																							
Bellefield	2	37.8	6.2	25.0	0.5	28.5	0.5	24.5	4.5										2	37.8	25.0	28.5	24.5
Holmes	3	25.0	5.0	25.1	0.9	22.0	2.2	21.8	2.4	3	36.3	2.7	31.5	3.1	28.2	1.6	27.9	2.0	6	30.6	28.3	25.2	24.8
Ave.	5	30.1	5.6	25.0	0.7	24.6	1.3	22.8	3.4	3	36.3	2.7	31.5	3.1	28.2	1.6	27.9	2.0	8	32.4	27.5	26.0	24.7
7 years (7^0-7^{11})																							
Bright																							
Bellefield	4	22.3	5.2	17.1	1.9	16.7	2.6	16.3	2.2										4	22.3	17.1	16.7	16.3
Colfax										6	22.4	2.7	20.0	1.8	18.6	2.2	17.8	2.3	6	22.4	20.0	18.6	17.8
Ave.																			10	22.3	18.8	17.8	17.1
Average																							
Bellefield	18	22.2	3.6	19.3	2.1	18.6	2.4	17.4	1.77	20	27.6	6.7	23.2	3.5	20.8	2.9	20.1	2.87	38	25.0	21.4	19.8	18.8
Holmes	43	26.3	5.8	20.8	3.2	20.6	3.6	19.1	2.78	45	25.7	3.7	20.8	2.6	19.9	2.5	18.8	1.9	88	26.0	20.8	20.3	18.9
Ave.	61	25.1	4.7	20.3	2.6	20.0	3.0	18.6	2.2	65	26.3	5.2	21.5	3.0	20.2	2.7	19.1	2.3	126	25.7	21.0	20.1	18.9
Dull																							
Bellefield	4	32.2	5.8	24.2	4.7	24.8	3.6	22.75	3.2										4	32.2	24.2	24.8	22.7
Holmes	10	30.4	7.0	24.6	3.0	23.7	4.6	22.6	3.7	8	36.3	10.3	26.0	4.2	23.8	3.2	22.7	3.8	18	33.0	25.2	23.7	22.6
Ave.	14	30.9	6.4	24.5	3.8	24.0	4.1	22.6	3.4										22	32.9	25.0	23.9	22.7
Ave. Ae. 7		26.0	5.4	20.9	2.9	20.6	3.3	19.2	2.7		27.1	5.8	21.9	3.0	20.4	2.7	19.4	2.7		26.5	21.4	20.5	19.3

10½ years

Bright

		1	18.8		17.6		15.0		15.0		2	17.4	15.1	14.5	13.8
	12.6	4	16.6	2.4	15.9	1.8	14.9	2.1	14.4	1.6	5	14.9	15.2	14.5	14.0
							14.0		14.5		7	15.6	15.2	14.5	13.9

10½ years (10-10)

Bright

Bellefield	1	16.0		12.6		14.0		12.6		1	18.8		17.6		15.0		15.0		2	17.4	15.1	14.5	13.8
Colfax	1	14.0		12.5		13.0		12.5		4	16.6	2.4	15.9	1.8	14.9	2.1	14.4	1.6	5	14.9	15.2	14.5	14.0
Ave.	2	15.0		12.5		13.5		12.5		5	15.8		16.2		14.9		14.5		7	15.6	15.2	14.5	13.9

Average

Bellefield	17	16.7	3.1	15.7	1.8	14.6	1.8	13.7	1.4	14	17.0	2.5	16.1	2.2	14.4	1.5	13.9	1.47	31	16.8	15.8	14.5	13.8
Holmes	25	18.0	2.3	14.8	15.6	15.0	16.1	14.2	1.5	24	17.4	2.4	15.7	1.8	15.5	2.4	14.4	1.6	49	17.7	15.2	15.2	14.3
Ave.	42	17.5	2.7	15.1	8.7	14.8	8.9	14.0	1.4	38	17.2	2.4	15.8	2.0	15.1	1.9	14.2	1.5	80	17.3	15.5	15.0	14.1

Dull

Bellefield	2	15.5	0.5	16.0	2.0	14.0	1.0	14.0	1.0										2	15.5	16.0	14.0	14.0
Holmes										1	25.8		17.6		17.0		17.0		1	25.8	17.6	17.0	17.0
Ave.																			3	18.9	16.5	15.0	15.0

10 years (10^0-10^{11})

Bright

Bellefield	2	16.4	0.4	13.3	0.7	18.5	4.5	13.3	0.7	1	18.8		17.6		15.0		15.0		3	17.2	14.7	17.3	13.8
Colfax	6	15.3	2.7	16.2	3.0	15.1	2.3	14.7	2.5	11	17.8	3.0	16.3	2.3	15.8	1.7	14.9	1.59	17	16.9	16.2	15.5	14.8
Ave.	8	15.6	1.5	15.4	1.8	15.9	3.4	14.4	1.6	12	17.9		16.3		15.7		14.9		20	17.0	16.0	15.8	12.7

Average

Bellefield	27	18.0	3.99	15.7	2.0	14.8	2.2	14.7	1.8	27	16.8	3.3	15.4	2.1	14.4	1.9	13.5	1.58	54	17.4	15.5	14.6	14.1
Holmes	28	17.1	2.0	15.1	1.6	15.0	1.4	14.4	1.4	36	18.2	2.8	15.8	1.6	15.9	2.2	14.7	1.66	64	17.7	15.4	15.4	14.5
Ave.	55	17.5	2.9	15.3	1.8	14.9	1.8	14.5	1.6	63	17.6	3.0	15.6	1.6	15.2	2.0	14.2	1.5	118	17.6	15.5	15.1	14.3

Dull

Bellefield	3	14.6	1.2	16.0	1.3	13.8	0.7	13.6	1.4	1	21.0		18.6		15.8		15.8		4	16.2	16.6	14.3	14.1
Holmes	6	18.6	2.8	17.6	3.9	15.3	1.4	14.1	0.9	2	26.7	0.9	17.4	0.2	17.5	0.5	17.1	0.1	8	20.6	17.6	15.8	14.8
Ave.	9	17.2	2.0	17.0	2.6	14.8	1.0	13.9	0.6	3	24.3		17.8		16.9		16.6		12	19.1	17.2	15.3	14.6
Ave. Ae. 10		15.9	2.1	15.6	2.0	15.0	2.0	14.4	1.4		19.9	2.5	16.8	1.5	15.7	1.5	14.4	1.2		17.6	15.7	15.2	14.4

TABLE IX

11 years (10^{10}-11^8)

School	Boys									Girls									Both Sexes				
	No.	I Ave.	M.V.	II Ave.	M.V.	III Ave.	M.V.	Sh. Ave.	M.V.	No.	I Ave.	M.V.	II Ave.	M.V.	III Ave.	M.V.	Sh. Ave.	M.V.	No.	I Ave.	II Ave.	III Ave.	Sh. Ave.
											Bright												
Bellefield	1	11.0		15.0		12.0		11.0		2	19.6	2.4	19.0	3.0	15.0	1.0	15.0	1.0	3	16.7	17.6	14.0	13.6
Colfax	1	17.0		17.0		17.0		17.0		8	18.3	3.7	17.0	2.9	16.1	2.3	15.2	2.1	9	18.2	16.9	16.1	15.4

Average																							
Bellefield	9	16.7	2.3	14.5	1.8	14.6	2.9	13.4	1.68	15	15.3	2.8	14.9	1.5	13.9	1.5	13.2	1.1	24	15.8	14.7	14.2	13.2
Holmes	15	16.6	2.7	15.4	2.4	14.9	1.9	14.1	1.4	21	18.3	2.5	16.7	2.0	15.2	1.5	14.8	1.1	36	17.6	16.2	15.1	14.5
Ave.	24	16.6	2.5	15.1	2.1	14.8	2.4	13.8	1.5	36	17.1	2.6	15.9	1.7	14.7	1.5	14.1	1.1	60	16.8	15.6	14.7	14.0
Dull																							
Bellefield	3	15.0	1.1	14.6	1.1	14.0	0.6	13.6	0.9	1	23.0		20.8		29.0		20.8		4	17.0	16.2	17.8	15.4
Holmes	4	16.9	1.9	16.1	1.5	14.4	1.3	14.1	1.1	1	19.0		23.0		14.0		14.0		5	17.3	17.4	14.3	14.1
Ave.	7	16.1	1.5	15.4	1.3	14.2	0.9	13.9	1.0	2	21.0		21.9		21.5		17.4		9	17.2	16.9	15.8	14.6
11½ years (11^4-11^9)																							
Bright																							
Colfax	4	13.5	0.9	14.3	1.6	13.5	0.8	12.8	1.3	1	17.0		15.0		13.2		13.2		5	14.2	14.4	13.5	12.8
Average																							
Bellefield	12	15.3	2.19	13.5	1.3	13.6	1.7	12.6	1.5	23	15.8	2.1	14.4	7.6	13.8	1.0	13.0	0.9	35	15.6	14.0	13.7	12.8
Holmes	17	15.8	1.9	17.2	2.8	14.4	1.1	13.7	1.5	20	17.7	3.6	17.2	2.2	14.4	1.2	14.0	1.2	37	16.8	16.3	14.4	13.9
Ave.	29	15.6	2.0	14.5	2.0	14.1	1.4	13.6	1.5	43	16.6	2.8	15.7	1.9	14.0	1.1	13.5	1.0	72	16.2	15.2	14.0	13.4
Dull																							
Bellefield										1	17.0		13.0		13.0		13.0		1	17.0	13.0	13.0	
Holmes	4	17.0	1.5	14.5	1.7	13.2	0.5	13.0	0.3	3	28.5	7.7	22.3	4.5	18.9	0.6	17.5	0.9	7	21.9	17.8	15.6	14.9
Ave.										4	25.6		19.9		17.4		16.4		8	21.3	17.2	15.3	14.7
11 years (11^0-11^{11})																							
Bright																							
Bellefield	2	13.0	2.0	16.0	1.0	13.5	1.5	13.0	2.0	2	19.6	2.4	19.0	3.0	15.0	1.0	15.0	1.0	4	16.3	17.5	14.2	14.0
Colfax	5	13.4	0.8	14.0	1.7	14.0	1.0	12.7	1.06	9	16.4	1.9	14.8	1.7	14.5	1.7	13.8	1.9	14	15.4	14.5	14.3	13.4
Ave.	7	13.2	1.4	15.0	1.3	13.8	1.2	12.8	1.5	11	17.0	2.1	15.5	2.3	14.5	1.3	14.0	1.4	18	15.6	15.1	14.3	14.2
Average																							
Bellefield	26	15.5	2.2	13.6	1.5	13.6	2.3	12.4	1.8	37	15.1	2.2	13.9	1.8	13.5	1.3	12.7	1.2	63	15.2	13.8	13.5	12.5
Holmes	30	15.5	1.9	14.8	2.2	14.0	1.0	13.3	1.2	39	18.0	3.08	16.5	2.2	14.6	1.3	14.2	1.19	69	16.9	15.7	14.3	13.8
Ave.	56	15.5	2.0	14.2	1.8	13.8	1.6	12.1	1.5	76	16.6	1.6	15.2	2.0	14.1	1.3	13.4	1.1	132	16.2	14.8	14.0	13.2
Dull																							
Bellefield	2	19.1	3.1	14.5	1.5	15.6	2.0	14.5	1.5	3	18.7	2.8	16.2	3.0	19.0	10.0	16.2	3.0	5	18.8	15.5	17.6	15.5
Holmes	9	16.0	1.4	14.8	1.6	13.8	1.4	13.2	0.88	5	26.6	6.8	21.2	3.8	17.6	1.6	16.5	1.2	14	19.8	17.1	15.1	14.3
Ave.	11	16.6	2.2	14.7	1.5	14.1	1.7	13.4	1.1	8	23.6	4.8	19.3	3.4	18.1	5.8	16.4	2.1	19	19.5	16.6	15.7	14.6
Ave. Ae. 11	4	15.4	1.9	14.3	1.5	13.8	1.5	12.7	1.3		17.2	3.1	15.6	2.5	14.5	2.8	13.8	1.5		16.4	15.0	14.2	13.4

											Bright												
Bellefield										1	10.0		9.0		14.0		9.0		1	10.0	9.0	14.0	9.0
Colfax										1	14.0		12.2		12.0		12.0		1	10.0	12.2	12.0	12.0
Ave.										2	12.0		10.6		13.0		10.5		2	12.0	10.6	13.0	10.5
											Average												
Bellefield	9	13.2	1.1	12.3	1.5	11.9	0.7	11.4	0.9	7	13.3	2.18	12.9	1.7	11.7	1.0	11.5	1.3	16	13.2	12.6	11.8	11.4
Holmes	6	15.0	1.9	14.5	0.9	14.7	3.2	12.8	1.2	5	14.3	2.5	12.2	0.6	11.2	1.4	11.3	1.1	11	14.7	13.4	13.4	12.1
Ave.	15	13.9	1.5	13.2	1.2	13.0	1.9	11.9	1.0	12	13.7	2.3	12.6	1.1	11.7	1.2	11.4	1.2	27	13.4	12.9	12.4	11.7
											Dull												
Bellefield	5	15.1	2.38	13.4	2.9	12.9	2.5	12.5	2.78	2	15.0	1.0	11.9	0.9	13.6	0.6	12.5	1.5	7	15.0	12.9	13.0	12.5
Holmes										6	15.6	1.5	15.6	2.3	13.9	0.6	13.0	0.3	6	15.6	15.6	13.9	13.0
Ave.										8	15.4	1.2	14.7	1.6	14.4	0.6	12.8	0.9	13	15.3	14.2	13.1	12.7
											14 years (14^{0}-14^{11})												
											Bright												
Bellefield										3	12.6	1.8	10.4	1.2	12.4	1.0	10.3	1.1	3	12.6	10.4	12.4	10.3
Colfax	1	12.0		14.0		14.0		12.0		2	13.6	0.4	11.6	0.6	12.0	0	11.5	0.5	3	13.0	12.6	12.6	11.6
Ave.										5	13.0	1.1	10.8	0.9	12.2	0.5	10.8	0.8	6	12.8	11.4	12.5	11.0
											Average												
Bellefield	22	13.4	1.3	12.0	1.3	11.6	1.8	11.0	1.0	13	12.8	1.67	12.7	1.7	11.5	1.7	11.1	1.6	35	13.2	12.3	11.5	11.0
Holmes	17	14.4	2.2	13.9	1.3	13.6	2.0	12.3	1.0	16	14.9	2.3	13.4	1.5	12.3	1.1	11.8	0.96	33	14.6	13.7	13.0	12.0
Ave.	39	13.8	1.7	12.8	1.3	12.5	1.9	11.5	1.0	29	13.9	1.9	13.1	1.6	11.9	1.4	11.5	1.2	68	13.9	13.0	12.2	11.5
											Dull												
Bellefield	7	14.5	2.0	13.1	2.1	12.3	2.4	12.0	2.28	2	15.0	1.0	11.9	0.9	13.6	0.6	11.9	0.9	9	14.6	12.8	12.6	12.0
Holmes	2	13.5	0.5	14.4	1.6	12.0	0.2	12.0	0.2	9	16.7	2.3	14.4	2.7	13.8	1.7	12.6	0.88	11	16.1	14.4	13.5	12.5
Ave.	9	14.3	1.2	13.4	1.8	12.2	1.3	12.0	1.2	11	16.4	1.6	13.9	1.8	13.8	1.1	12.5	0.8	20	15.4	13.7	13.1	12.3
Ave. Ae. 14		13.9	1.5	13.0	1.5	12.4	1.6	11.6	1.1		14.4	1.5	13.1	1.4	12.4	1.2	11.6	0.9		14.1	13.0	12.4	11.6

TABLE XIII

15 years (14^{10}-15^{8})

School	Boys									Girls									Both Sexes				
		I		II		III		Sh.			I		II		III		Sh.			I	II	III	Sh.
	No.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	No.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	Ave.	M.V.	No.	Ave.	Ave.	Ave.	Ave.
											Bright												
Bellefield	1	14.2		11.8		13.0		13.0											1	14.2	11.8	13.0	13.0

Bellefield	3	12.3	0.4	12.3	0.8	10.5	0.8	10.4	0.8	5	12.9	1.3	13.6	0.7	11.4	1.2	11.4	1.2	8	12.7	13.1	11.0	11.0
Holmes	6	12.7	0.9	13.6	0.9	11.9	0.6	11.4	0.5	5	15.2	2.6	13.5	0.5	12.9	1.9	11.9	1.18	11	13.8	13.6	12.4	11.6
Ave.	9	12.6	0.6	13.2	0.8	11.4	0.7	11.1	0.6	10	14.1	1.9	13.6	0.6	12.1	1.5	11.6	1.1	19	13.3	13.4	11.8	11.4
Dull																							
Bellefield										1	13.2		11.0		12.0		11.0		1	13.2	11.0	12.0	11.0
Holmes	2	15.9	1.9	15.0	1.0	12.4	0.6	12.4	0.6	5	15.4	2.5	12.6	3.0	11.7	3.0	11.5	0.9	7	15.5	13.2	11.9	11.8
Ave.										6	15.0		12.3		11.7		11.4		8	15.2	13.0	11.9	11.7
15½ years (15⁴-15⁹) Bright																							
Colfax										1	15.2	12.5	12.5		13.0		12.5		1	15.2	12.5	13.0	12.5
Average																							
Bellefield	3	11.4	0.8	12.4	2.4	9.8	0.9	9.7	0.8										3	11.4	12.4	9.8	9.7
Holmes	2	13.5	0.5	12.4	0.4	17.5	4.5	12.4	0.4	1	13.2		14.0		12.0		12.0		3	13.4	12.9	15.6	12.2
Ave.	5	12.2	0.6	12.4	1.4	12.8	2.7	10.8	0.6										6	12.4	12.6	12.7	11.0
Dull																							
Bellefield										1	13.0		10.0		9.0		9.0		1	13.0	10.0	9.0	9.0
Holmes	2	16.7	0.3	12.2	0.2	12.3	1.3	11.5	0.5	1	15.4		13.0		12.0		12.0		3	16.2	12.4	12.2	11.6
Ave.										2	14.2		11.5		10.5		10.5		4	15.4	11.8	11.4	11.0
15 years (15⁰-15¹¹) Bright																							
Bellefield	1	12.8		11.0		9.4		9.4											1	12.8	11.0	9.4	9.4
Colfax										1	15.2		12.5		13.0		12.5		1	15.2	12.5	13.0	12.5
Ave.																			2	14.0	11.7	11.2	10.9
Average																							
Bellefield	7	12.1	1.5	11.5	1.4	10.4	1.2	10.2	1.0	3	13.7	1.0	14.0	0.7	11.8	1.0	11.8	1.0	10	12.6	12.3	10.8	10.7
Holmes	4	13.5	0.5	13.2	0.8	14.5	3.7	11.9	0.5	4	15.4	2.4	13.7	0.4	13.7	2.1	12.7	0.7	8	14.4	13.4	14.1	12.3
Ave.	11	12.6	1.0	12.1	1.1	11.9	2.4	10.8	0.7	7	14.9	1.7	12.4	0.5	12.9	1.5	12.3	0.8	18	13.4	12.8	12.3	11.4
Dull																							
Bellefield										2	13.1	0.1	10.5	0.5	10.5	1.5	10.0	1.0	2	13.1		10.5	20.0
Holmes	3	17.0	0.4	12.8	0.8	12.5	1.0	12.0	1.0	7	15.2	2.0	12.6	0.9	12.1	1.0	11.7	0.8	10	15.7	12.6	12.2	11.8
Ave.										0	14.7	1.0	12.1	0.7	11.7	1.2	11.30	0.9	12	15.3	12.3	11.9	11.5
Ave. Ae. 15		13.6	0.8	12.2	1.0	11.8	1.9	11.0	0.8		14.7	1.3	12.8	0.6	12.2	1.4	11.8	1.1		14.1	12.5	11.7	11.4

TABLE XVIII

Binet-Simon Age IV

	Borderline					Backward					Retarded			
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
Boys														
	1	47.	26.6	28.	26.6	1	49.	45.	47.	45.	1	65.	41.6	38.6
Girls														
Both Sexes (Averages)														

TABLE XIX

Binet-Simon Age V

Boys														
39.4						2	78.	49.3	66.9	49.3				
							27.	4.7	16.1	4.7				
Girls														
24.						2	55.6	37.1	32.4	32.4				
							10.6	3.1	7.2	7.2				
Both Sexes (Averages)														
31.7						4	66.8	43.2	49.6	40.8				
							18.8	3.9	11.6	5.9				

TABLE XX

Binet-Simon Age VI

	Borderline					Backward					Retarded			
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
Boys														
	3	35.6	27.2	28.5	27.	6	42.9	35.7	29.	26.5	5	40.1	43.2	29.9
		6.1	5.	6.4	4.9		19.4	5.7	3.7	4.5		10.6	14.5	5.0
Girls														
						3	44.8	29.5	27.4	26.9				
							20.	5.6	7.0	7.3				
Both Sexes (Averages)														
						9	43.5	33.6	28.4	26.6				
							19.7	5.6	5.3	5.9				

TABLE XXI

Binet-Simon Age VII

Boys														
4.	3	27.8	21.9	23.6	21.9	19	35.	25.	24.2	23.0	7	34.5	26.4	21.7
7.4		7.4	1.9	2.4	1.5		7.3	4.1	4.6	3.8		7.8	6.1	3.1
Girls														
2.2	3	31.6	39.8	29.6	24.5	7	45.6	27.3	27.	25.8	2	52.	31.2	27.8
6.1		9.7	12.8	2.4	5.		18.2	6.5	8.4	6.7		4.	2.8	5.8
Both Sexes														
3.3	6	29.7	30.8	26.	23.2	26	37.9	25.7	25.	23.7	9	38.4	27.4	23.
6.7		8.5	7.3	2.4	3.1		12.7	5.3	6.5	5.2		5.9	4.4	4.4

	Normal					Bright					All Grades				
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.
3.6						2	99.	110.	48.	48.	13	94.4	65.5	52.8	46.6
							60.	59.	2.	2.	M.V.	60.0	36.1	9.4	7.0
	2	99.	110.	48.	48.						4	160.8	72.8	55.2	51.2
											M.V.	73.2	34.8	16.2	16.2
											17	109.5	66.9	53.2	47.5
											M.V.	66.6	35.4	12.8	11.6
	1	169	96.	72.	72.						9	72.3	53.0	52.3	45.3
											M.V.	22.6	9.7	15.9	8.7
	1	70.	108.	53.4	53.4	1		73.6			8	54.9	49.1	36.6	35.3
											M.V.	8.2	7.4	11.9	9.9
	2	119.0	102.	62.7	62.7						17	64.7	51.1	45.4	40.9
											M.V.	15.4	8.5	13.9	9.3

	Normal					Bright					All Grades				
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.
8.0	3	43.	43.8	42.4	35.6						28	45.1	36.9	32.4	29.0
3.8		21.6	14.8	15.8	14.3						M.V.	15.0	9.6	7.7	7.3
						1	50.	37.8	33.2	33.2	7	47.8	31.9	30.9	29.8
											M.V.	2.6	4.0	4.9	4.9
											35	45.6	35.9	32.2	23.7
											M.V.	8.8	6.8	6.3	6.1
1.7	8	36.8	24.7	25.9	22.6	2	32.	26.1	24.	23.	55	35.7	26.3	24.8	23.3
3.1		8.6	2.3	6.1	3.5		5.	4.1	1.	1.5	M.V.	8.8	5.0	4.9	3.8
5.2	2	42.5	35.	27.	27.	2	30.7	23.	22.8	21.5	27	39.4	29.8	26.5	24.5
3.2		2.5					2.3	2.	.8	.5	M.V.	8.8	6.6	4.7	3.8
2.5	10	38.	26.7	26.1	23.4	4	31.3	24.5	23.4	22.5	82	36.9	27.5	25.3	23.7
3.1		5.5					3.6	3.	.9	1.	M.V.	8.8	5.8	4.8	3.8

Ave. Chron. Age	Ave. B.-S. Age		Moron					Borderline					B
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I
11.2	8.6	16	35.9	26.9	22.2	21.0	8	25.4	22.4	19.8	19.0	14	27.2
M.V.			13.9	9.7	4.8	4.1		4.9	3.7	3.5	3.0		7.2
10.9	8.4	6	42.9	27.6	26.4	24.4	6	28.5	22.0	20.4	18.9	9	28.2
M.V.			28.5	11.7	10.2	8.5		6.3	4.7	4.3	3.6		7.2
11.1	8.5	22	37.8	26.0	23.3	21.9	14	26.7	22.1	20.0	19.0	23	27.6
M.V.			21.2	10.7	7.5	6.3		5.6	4.2	3.9	3.3		7.2
11.9	9.3	9	30.3	18.7	19.2	17.5	9	24.9	19.2	19.2	18.4	21	25.6
M.V.			9.1	3.4	3.2	2.3		3.7	2.7	3.5	3.0		4.4
11.9	9.2	3	25.4	23.8	19.3	19.3	3	25.6	20.4	19.7	15.8	6	23.6
M.V.			1.6	1.4	1.7	1.7		5.1	2.7	5.6	1.2		5.0
11.9	9.3	12	29.0	20.0	19.2	18.0	12	25.1	19.5	19.3	16.9	27	25.2
M.V.			5.3	2.4	2.4	2.0		4.4	2.7	4.5	2.1		4.7

Ave. Chron. Age	Ave. B.-S. Age		Moron					Borderline					B
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I
12.6	10.4	4	26.8	22.2	19.2	19.	9	21.2	16.1	15.9	15.3	18	22.2
M.V.			6.5	5.6	5.1	5.1		5.3	1.8	1.7	1.7		4.8
13.0	10.3	3	28.4	19.	17.7	17.	4	20.7	19.1	15.4	15.2	8	21.6
M.V.			2.4	2.6	2.2	2.6		2.	3.3	1.2	1.4		2.8
12.8	10.3	7	27.6	20.6	18.4	18.	13	20.9	17.6	15.6	15.2	26	21.9
			4.4	4.1	3.9	3.9		3.6	2.5	1.4	1.5		3.8
14.1	11.1						5	20.1	16.9	15.4	14.6	18	20.4
M.V.								2.3	2.3	1.6	.8		2.6
12.5	11.3	1	21.0	21.4	16.0	16.0	1	16.2	13.8	13.0	13.0	4	19.9
M.V.													2.5
13.3	11.2						6	18.1	15.3	14.2	13.8	22	20.1
M.V.													2.5

TABLE XXII
Binet-Simon Age VIII

ckward					Retarded						Normal			B	
II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	
					Boys										
20.4	19.3	18.2	6	3.84	29.7	36.0	29.0	5	31.9	23.9	25.6	22.6			
5.5	2.5	2.3		13.8	12.4	18.3	12.6		3.5	1.	4.9	2.2			
					Girls										
19.3	18.6	17.9	1	28.4	45.6	20.0	20.0						2		
2.3	2.	1.9													
					Both Sexes (Averages)										
20.0	19.1	18.0	7	37.0	32.0	33.7	27.7								
3.9	2.2	2.1													

TABLE XXIII
Binet-Simon Age IX

					Boys										
19.4	17.9	17.4	6	21.8	18.8	18.0	17.9	4	26.3	21.2	21.6	20.5			
3.7	2.9	2.8		1.9	1.9	1.5	1.7		3.3	2.0	2.0	1.4			
					Girls										
19.1	17.2	16.5	3	24.6	16.6	17.9	16.2	4	23.7	20.3	19.7	19.0	2	28.0	
3.1	1.6	1.8		2.8	.8	1.7	.5		4.7	4.8	3.6	4.0	M.V.	3.0	
					Both Sexes (Averages)										
19.3	17.8	17.2	9	22.7	18.1	18.0	17.3	8	25.0	20.7	20.6	19.6			
3.4	2.2	2.3		2.3	1.3	1.6	1.1		4.0	3.4	2.8	2.7			

TABLE XXIV
Binet-Simon Age X

kward					Retarded						Normal			B	
II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	
					Boys										
17.5	16.1	15.5	15	21.9	18.7	17.3	16.3	7	25.6	18.4	17.	15.7			
2.7	2.3	2.3		4.8	3.3	3.3	2.4		3.5	2.5	1.3	.7	1	22.0	
					Girls										
17.3	17.4	15.8	1	27.8	22.0	16.0	16.0	4	21.1	18.5	16.9	16.1			
1.9	2.7	1.8							2.1	2.2	.8	.7			
					Both Sexes (Averages)										
17.4	16.7	15.6	16	24.9	20.3	16.6	16.1	11	23.3	18.4	16.9	15.8			
2.3	2.5	2.							2.8	2.3	1.	.7			

TABLE XXV
Binet-Simon Age XI

					Boys										
5.9	14.8	14.5	5	19.8	14.9	14.4	14.0	1	16.2	15.4	14.4	14.4			
2.2	1.9	.9		3.8	1.1	1.6	1.1								
					Girls										
9.2	17.1	17.0	3	19.8	17.4	14.6	14.6	1	16.0	14.2	14.2	14.2	4	19.6	
3.2	4.1	3.9		.9	1.1	.9	.9							.9	
					Both Sexes (Averages)										
7.5	15.9	15.7	8	19.8	16.1	14.5	14.3	2	16.1	14.8	14.3	14.3			
2.7	3.	2.4		2.3	1.1	1.2	1.								

e. n. e	Ave. B.-S. Age	Idiot					Imbecile					Borderline			
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
43	5.3						1	70.0	80.0	70.0	70.0				
5	7.6														
4	5.6														
.51 V.	5.3	1		180.0			2	149.0 6.0	75.0 5.0		70.0	1	47.0	26.6	28.0
72	7.4														
56 V.	5.7														

e. n. e	Ave. B.-S. Age	Imbecile					Moron					Borderline			
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
.51 V.	6.2	6	86.5 41.1	51.9 18.5	49.9 4.5	38.8 5.4	1	50.0	39.4	44.0	39.4				
7.43 .V.	6.08	2	237.2 67.2	135. 15.	69.0	69.0	1	34.0	27.0	24.0	24.0				
7.46 .V.	6.1	8	124.2 54.1	72.6 16.7	53.7	43.1	2	42.0	33.2	34.0	21.7				
8.43 M.V.	7.16	5	95.8 53.7	59.0 9.8	49.5 6.7	48.5 9.9						1	37.4	28.0	28.4
8.6 M.V.	7.7														
8.47 M.V.	7.3														

TABLE XXXI

Chronological Age 5

			Backward					Retarded					Normal	
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
			Boys											
	1	49.0	45.0	47.0	45.0	1	65.0	41.6	38.6	38.6	1	169.0	96.0	72.0
			Girls											
			Both Sexes (Averages)											

TABLE XXXII

Chronological Age 6

			Boys											
26.6	3	55.5	39.4	38.2	36.2	2	30.8	35.0	35.7	30.8	3	46.8	42.3	40.9
		9.6	7.1	8.3	5.7		.8	4.0	4.3	.8		7.2	15.7	16.8
			Girls											
	1	66.2	40.2	39.6	39.6						1	40.0	35.0	27.0
			Both Sexes (Averages)											
	4	58.2	39.6	38.6	37.0						4	45.1	40.5	37.4

TABLE XXXIII

Chronological Age 7

			Backward					Retarded					Normal	
Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II	III
			Boys											
	7	43.5	35.9	29.8	27.4	4	43.2	38.4	23.6	23.6	5	30.2	24.4	26.8
		3.2	1.1	4.8	5.7		11.7	15.2	3.7	3.7		3.7	.8	6.
			Girls											
	3	49.0	33.6	28.0	28.0	1	56.0	28.4	33.6	28.4	1	45.0	35.0	27.0
		17.0	3.4	6.6	6.6									
			Both Sexes (Averages)											
	10	45.1	35.2	29.3	27.6	5	45.8	36.4	25.6	24.5	6	32.7	26.2	26.8
		10.1	2.2	5.7	6.1									

TABLE XXXIV

Chronological Age 8

			Boys											
28.0	10	42.7	28.2	30.0	26.2	7	30.4	24.2	22.7	21.8	7	30.9	23.2	22.4
		13.2	5.4	11.4	6.1		6.2	5.0	3.7	3.2		4.5	1.4	2.7
			Girls											
	5	44.4	27.5	26.5	25.8	1	48.0	34.0	22.0	22.0	2	25.0	22.8	20.2
		18.2	3.5	3.7	3.2							5.	7.2	6.8
			Both Sexes (Averages)											
	15	43.2	28.0	28.9	26.1	8	32.6	25.3	22.6	21.8	9	29.6	23.1	21.9
		15.7	4.4	7.5	4.6							4.7	4.3	4.7

Normal
II III

96.0 72.0

42.3 40.9
15.7 16.8

35.0 27.0

0.5 37.4

mal
III

4 26.8
8 6.

27.0

26.8

22.4
2.7

20.2
6.8

1.9
.7

ve. ron. ge	Ave. B.-S. Age		Imbecile					Moron					Borderli	
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II
2.36	9.68	2	34.7	37.5	32.0	29.5	8	48.7	38.3	29.7	28.4	5	30.3	23.0
.V.			8.7	1.5	9.0	6.5		30.2	19.3	12.3	11.4		6.9	6.4
2.41	8.79	2	49.5	36.4	32.2	31.0	4	28.3	20.0	22.0	18.9	4	30.9	18.7
.V.			5.5	6.4	.2	.1		3.1	3.3	5.4	2.7		7.0	2.4
2.38	9.39	4	42.1	36.8	32.1	30.2	12	41.8	32.2	27.1	25.2	9	30.6	21.1
.V.			7.1	3.9	4.6	3.7		16.7	11.3	8.9	7.0		7.0	4.4

Ave. hron. Age	Ave. B.-S. Age		Imbecile					Moron					Borderli	
		No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II
13.42	9.3	5	87.8	45.6	57.4	42.4	9	27.6	23.8	18.6	18.0	5	22.3	18.8
.V.			60.7	15.4	38.8	16.8		4.7	6.3	2.3	1.9		2.2	3.0
3.41	10.44						1	23.0	23.0	22.0	22.0	4	22.6	22.1
.V.													4.9	1.4
13.43	9.5						10	27.1	23.7	18.9	18.4	9	22.4	20.3
M.V.													3.5	2.2

14.36	9.8	4	40.7	31.8	22.8	22.8	9	35.2	20.5	20.2	18.2	7	19.9	16.3
M.V.			9.8	5.7	2.6	2.6		18.8	6.5	4.8	4.1		2.5	1.5
14.38	9.7						4	21.0	17.2	16.2	16.1	3	19.5	15.5
M.V.								3.7	2.	1.6	1.8		2.2	3.2
14.36	9.8						13	30.8	19.5	19.0	17.5	10	19.7	16.1
M.V.								11.2	4.2	3.2	2.9		2.3	2.3

TABLE XXXVIII

Chronological Age 12

ne		Backward					Retarded					Norma		
III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II
				Boys										
20 9	20.8	12	22.7	17.4	17.2	16.3	5	19.0	18.8	15.1	14.9	2	15.8	14.0
3.4	4.0		4.2	3.3	2.5	3.2		3.1	6.8	2.1	1.9		1.6	1.0
				Girls										
23.6	18.0	4	21.9	17.7	15.2	15.0	2	23.7	17.5	17.8	16.0			
4.0	2.8		2.1	1.9	1.2	1.0		5.3	.5	2.8	1.0			
				Both Sexes (Averages)										
21.8	19.2	16	21.2	17.6	16.7	16.0	7	20.3	18.4	15.9	15.2			
3.7	3.4		3.1	2.6	1.8	2.1		4.2	3.6	2.5	1.4			

TABLE XXXIX

Chronological Age 13

te		Backward					Retarded					Norma		
III	Sh.	No.	I	II	III	Sh.	No.	I	II	III	Sh.	No.	I	II
				Boys										
16.8	16.4	12	22.3	17.0	15.1	15.0	6	17.6	16.0	14.9	14.3	1	19.0	12.0
1.5	1.9		3.3	2.7	1.5	1.6		2.3	1.4	2.6	1.5			
				Girls										
15.8	15.8	3	21.9	19.6	19.6	18.6	2	20.5	17.2	14.5	14.5			
.7	.7		2.0	4.0	3.8	4.2		.5	1.4	1.1	1.1			
				Both Sexes (Averages)										
16.3	16.1	15	22.2	17.5	16.0	15.7	12	18.3	16.3	14.8	14.4			
1.1	1.3		2.6	3.3	2.7	2.9		2.4	1.4	1.8	1.3			

TABLE XL

Chronological Age 14

				Boys							
15.4	15.0	11	18.4	15.3	13.7	13.7	3	16.6	14.0	14.4	13.3
.8	.6		2.2	.9	.9	.9		4.0	1.0	2.0	1.3
				Girls							
14.2	13.9	3	18.2	16.3	14.0	14.0					
1.4	1.6		1.1	1.6	.07	.07					
				Both Sexes (Averages)							
15.0	14.7	14	18.4	15.5	13.8	13.8					
1.1	1.1		1.6	1.2	.4	.4					

TABLE XLIV
Chronological Age 18

Boys

Ave. Chron. Age	Ave. B.-S. Age	Moron No.	I	II	III	Sh.	Borderline No.	I	II	III	Sh.	Backwar No.	I	II	III	S
18.45	12.6						1	20.2	15.0	15.2	15.0	1	20.0	17.0	15.0	15

TABLE XLV
Chronological Age 19

Boys

Ave. Chron. Age	Ave. B.-S. Age	Moron No.	I	II	III	Sh.	Borderline No.	I	II	III	Sh.	Backwar No.	I	II	III	S
19.16	11.2						1	22.0	21.4	14.2	14.2					

TABLE XLVI
Chronological Age 25

Boys

Ave. Chron. Age	Ave. B.-S. Age	Moron No.	I	II	III	Sh.	Borderline No.	I	II	III	Sh.	Backwar No.	I	II	III	S
25.66	13											1	21.0	17.4	13.8	13

TABLE XLVII
Chronological Age 33

Girls

Ave. Chron. Age	Ave. B.-S. Age	Moron No.	I	II	III	Sh.	Borderline No.	I	II	III	Sh.	Backwar No.	I	II	III	S
33.16	9.8	1	26.2	26.0	18.0	18.0										

Chron., chronological. B.-S., Binet-Simon. Ave., average. No., number of cases.
third trials. Sh., averages of the fastest record made during the three trials. All
grades or groups of intelligence given in each age. Unit of measurement, 1 second.
averages. M.V., mean variation. The chronological age has always been computed t

TABLE XLIX
YEARLY NORMS FOR NORMAL CHILDR

Age	Wallin Boys No.	Wallin Boys Ave.	Wallin Girls No.	Wallin Girls Ave.	Wallin B. & G. No.	Wallin B. & G. Ave.	Sylveste B. & G. No.
$2(2^0\text{-}2^{11})$							7
$3(3^0\text{-}3^{11})$			1	53.0			9
$4(4^0\text{-}4^{11})$	9	27.8	13	28.7	22	28.4	35
$5(5^0\text{-}5^{11})$	19	24.6	31	25.8	50	25.4	80
$6(6^0\text{-}6^{11})$	64	21.8	49	22.4	113	22.1	170
$7(7^0\text{-}7^{11})$	79	19.2	79	19.4	158	19.3	173
$8(8^0\text{-}8^{11})$	68	16.6	79	16.5	147	16.5	206
$9(9^0\text{-}9^{11})$	82	14.9	85	16.2	167	15.6	214
$10(10^0\text{-}10^{11})$	72	14.4	78	14.4	150	14.4	221
$11(11^0\text{-}11^{11})$	74	12.7	95	13.8	169	13.4	172
$12(12^0\text{-}12^{11})$	90	12.3	64	12.6	154	12.4	141
$13(13^0\text{-}13^{11})$	66	12.3	77	12.6	143	12.5	80
$14(14^0\text{-}14^{11})$	49	11.6	45	11.6	94	11.6	80
$15(15^0\text{-}15^{11})$	15	11.0	17	11.8	32	11.4	
$16(16^0\text{-}16^{11})$	6	10.2	5	11.6	11	10.9	
$17(17^0\text{-}17^{11})$	2	9.3	2	10.9	4	10.2	

No., number of cases. Ave., average time in seconds. B., boys. G., girls.

S

			All Grades		
	No.	I	II	III	Sh.
.0	2	20.1	16.0	15.1	15.0
	1	22.0	21.4	14.2	14.2
8	1	21.0	17.4	13.8	13.8
	1	26.2	26.0	18.0	18.0

I, II, III, first, second and
Grades, averages of all
he figures given represent
two decimal points.

S

EN

r	Goddard B. & G.		Sylvester, Goddard, Wallin	
ve.	No.	Ave.	No.	Ave.
2			7	92
9			10	67.4
6			57	39.2
37.6	17	29.5	146	32.5
26.5	26	27.5	309	24.9
23.3	25	24.5	356	21.6
20.5	28	21.8	381	19.0
18.7	47	19.3	428	17.5
6.7	49	18.2	420	16.0
14.9	38	17.6	380	14.4
13.8	20	15.9	315	13.2
12.6			223	12.5
11.6			174	11.6
			32	11.4
			11	10.9
			4	10.2

TABLE

HALF-YEARLY FORM-BOARD N

Age	Boys	
	No.	Ave.
4 $(3^{10}-4^{8})$	3	32.2
4½ $(4^{4}-4^{9})$	6	26.8
5 $(4^{10}-5^{8})$	6	24.5
5½ $(5^{4}-5^{9})$	11	24.7
6 $(5^{10}-6^{8})$	26	23.6
6½ $(6^{4}-6^{9})$	39	21.8
7 $(6^{10}-7^{8})$	43	20.1
7½ $(7^{4}-7^{9})$	40	18.5
8 $(7^{10}-8^{8})$	40	18.0
8½ $(8^{4}-8^{9})$	28	15.6
9 $(8^{10}-9^{8})$	40	15.5
9½ $(9^{4}-9^{9})$	38	14.6
10 $(9^{10}-10^{8})$	38	14.8
10½ $(10^{4}-10^{9})$	46	13.9
11 $(10^{10}-11^{8})$	33	13.7
11½ $(11^{4}-11^{9})$	37	13.2
12 $(11^{10}-12^{8})$	40	12.6
12½ $(12^{4}-12^{9})$	50	12.1
13 $(12^{10}-13^{8})$	44	12.2
13½ $(13^{4}-13^{9})$	29	11.6
14 $(13^{10}-14^{8})$	31	11.9
14½ $(14^{4}-14^{9})$	20	12.1
15 $(14^{10}-15^{8})$	12	11.4
15½ $(15^{4}-15^{9})$	7	11.0
16 $(15^{10}-16^{8})$	7	11.7
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APPARATUS AND EXPERIMENTS
ON
SOUND INTENSITY

BY

A. P. WEISS
Ohio State University

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APPARATUS AND EXPERIMENTS ON SOUND INTENSITY[1]

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[1] Submitted in partial fulfilment of the requirements for the degree of doctor of philosophy in the graduate school of the University of Missouri, 1916.

INTRODUCTION

Among the reasons why the attribute of intensity has not received the consideration in experimental investigations which has been given to other attributes of auditory perception, are especially the technical difficulty in controlling the intensity of tones and the lack of a convenient standard of tone intensity. There is no standard of tone intensity which is as available in psychological laboratories, as is the candle power for light intensity. Besides these, further difficulties appear in producing pure tones, in varying the intensity in a measurable manner and in maintaining a constant intensity.

The first step in this investigation was the construction of an apparatus by which the intensity of the tones to be used can be controlled.

The physicists who are best prepared to design the apparatus are not interested in the problem of tone intensity as it presents itself to the psychologist and for this reason it was found necessary to design and construct the apparatus in the psychological laboratory.

The problem was suggested to the writer while a student assistant in the laboratory, by Professor M. F. Meyer in 1909. The writer takes this occasion to acknowledge the great help he has received from Dr. Meyer throughout the entire time that he was working on the experiment,—assistance and encouragement which extended to every phase of the problem—mechanical, theoretical and practical. Because of Professor Meyer's wide experience with auditory phenomena in general and because of the fact that he had already started the problem, the writer was able to go ahead in a more direct path than would have been possible had it been necessary for him to work independently.

The apparatus difficulties passed through four relatively distinct stages, which will be considered in some detail in the description of the preliminary apparatus. It is considered worth while to describe these preliminary experiments so that others who may take up the problem of tone intensity apparatus may be spared some of the difficulties which were encountered.

It was continually borne in mind that tone intensity relations are an important part in nearly every investigation in audition. This is one reason why the apparatus has become so complicated. The following are some problems in which tone intensity plays a role. It also represents a provisional program of experimental work which it is hoped may some time be completed by the use of this apparatus.

Influence of phase on the intensity of tones.

Relative intensity of difference and combinational tones.

Relation between vocality and intensity.

Relation between tonality and intensity.

Effect of intensity on the consonance or dissonance of intervals.

Effect of intensity upon the apparent pitch.

Effect of intensity on pitch discrimination.

Limen for intensities.

Effect of intensity on the analysis and synthesis of tones.

Experiments in audition are more discontinuous than they are in vision. It is not likely that we will soon have pure tones which can be made very loud, and whose vibration rates can be made to vary quickly between the limits of audition, in the same way that brightness or saturation is now varied in vision. For this reason the usual experiment in tones will be restricted to relatively few tones or intervals.

The whole tonal scale must be worked over gradually but as the technique develops and the body of facts is extended much more satisfactory work can be done on the various theories of audition. Most of the current theories on audition were built upon considerations which were mainly qualitative in character. A theory, however, is of greatest use when it aids in also predicting quantitative relations.

The apparatus also lends itself well to experiments in vision in which it is necessary to have a constant illumination. The alternating current which passes through the sockets 36, fig. 4, is about as constant an electrical current as can be produced. With the proper Mazda lamp the apparatus will furnish an unvarying light up to about 100 candle power. Where vision and audition are to be combined in an experiment this fact is of especial importance.

I. PURPOSE AND SCOPE OF THE APPARATUS

The apparatus was designed:

1. To produce a number of pure tones.
2. To control the tone intensity.
3. To control the phase relations.

1. The test for a pure tone was the unitary character of the auditory impression. A tone was judged to be pure when a careful and attentive analysis by the unaided ear did not reveal overtones or upper harmonics of the forks or resonators. As a part of the apparatus consisted of the carefully tuned resonators 150, 200, 250, 300, 350, 400, 450, any tones having these periods could be readily detected, if present as overtones or asymmetry[1] tones. The extent to which an objective search for overtones was made was limited to these resonators. Disturbing tones and noises that were present to the ear were localized with a short piece of rubber tubing, one end of which was held to the ear while the different parts of the apparatus were explored with the other end. Such tones were usually caused by loose washers, the millimeter scales rattling against the resonators, etc. When once located they were usually easy to eliminate.

2. To make judgments of intensity, it is necessary that the tones can be started and stopped without any pronounced variation in the character of the tone at the beginning and end. A fork always changes its character when suddenly stopped and several seconds are required before an electrically driven fork reaches its constant amplitude. For this reason the forks were kept vibrating all the time and the tone generated in the resonator was the one started and stopped by a felt covered shutter. If the resonator is carefully tuned and properly adjusted over the fork, the tones "just slide in and out" quickly but with neither the beginning nor the end specifically marked.

---

[1] F. Lindig, Ann. d. Phys. vol., 11, p. 31 ff. 1903. Ueber Asymmetrietoene. M. F. Meyer, ibid, vol. 12, p. 889. 1904. Ueber Kombinations- und Asymmetrietoene.

The intensity of the tones was controlled by shifting the resonators to different distances from the forks. The mechanical details will be described in the Method of Experimentation.

3. By phase control is meant our being able to determine how the sound waves reach the ear relative to each other. This is of considerable theoretical importance because the character of the resulting sound wave, when a number of tones are sounding at the same time, depends very much upon the phase relations.

1. PRELIMINARY APPARATUS

Work on the apparatus was begun with a special set of tuning forks of the frequencies 150, 200, 250, 300, 350, 400, 450, 500. These were mounted on resonance boxes. They were to be kept vibrating by air impulses of the same frequency, blown into the resonance boxes of the forks. To secure air impulses of the proper frequency, a motor[2] was made whose magnetic fields were made and broken by an electrically driven tuning fork. This motor would run only when its rate of rotation synchronized with the vibration rate of the fork. Any tendency to run faster or slower would result in an acceleration or retardation such that it was forced into step with the fork. On the shaft of this motor was mounted a series of sirens with rectangular holes. Air under pressure was interrupted by these holes and led to the mouth of the resonator on the tuning fork. It was hoped that these air puffs would keep the tuning forks vibrating steadily and strongly.

The forks were not to furnish the tones to be used in experimenting, but were to act as generators of sinusoidal-electric currents which acted on a telephone receiver located in the piston of an adjustable resonator. On one of the prongs of these forks was fastened a coil of copper wire which moved inside of an annular coil on the opposite prong of the fork. When the forks were vibrating, these coils moved over and within each other in the same form of motion as that in which the fork prongs were moving. Since the prongs moved in a purely sinusoidal form of motion a constant electric current that was sent through one of the coils, would induce an alternating current having a sinusoidal form in the other coil. This alternating current then passed through the telephone resonator. It was found, however, that the tone was too weak and not pure.

---

[2] The motor was built on the same principle as the "phonic wheel" described by Lord Rayleigh. Theory of Sound, vol. I, p. 67. The motor was constructed by Max Kohl, Chemnitz, Germany.

The amplitude of the forks and the number of turns on the coils were not great enough to produce alternating currents which were strong enough to cause a strong tone in the telephone resonator. The vibrations of the telephone diaphram were furthermore not of a single sinus form, as was demonstrated by the presence of overtones. The diaphram vibrated not only in the forced period of the alternating current generated by the forks but also in other periods, due probably to the manner in which the metal and internal stresses were distributed over the disk and to the hysterisis effects of the magnet. At the time, it was thought that the difficulty was merely one of securing stronger electric currents. The air puffs did not seem to set the forks into vibration as strongly as was thought necessary to get the best results from the coils on the prongs of the forks.

It was then decided to drive the forks electrically. They could not be driven in the ordinary manner of electrically driven forks, because it was desirable to control their phase. To do this it is necessary that the moving parts that make the interruptions should be the same for all the forks. When the forks were being driven by the air puffs, this object was achieved by the common shaft upon which the sirens were mounted. It was decided to use a similar principle in producing the electrical interruptions which were now to drive the forks. Instead of having a number of seperate disks, a large disk of one-fourth inch copper and sixteen inches in diameter, was made. This disk had nine rows of holes of 10, 20, 30, 40, 50, 60, 70, 80, 90 holes to the row. These holes were filled with hard rubber plugs and the whole face of the disk ground to a plane surface. A series of bronze contact springs placed over the rows of holes opened and closed an electric circuit as the plugs and copper alternately passed under the contact points.

When the disk was driven at the rate of five revolutions per second, the various circles produced interrupted currents of the frequencies 50, 100, 150, 200, 250, 300, 350, 400, 450 per second. By sending these interruptions through the magnets of tuning forks of corresponding vibration rates, these forks would be set in vibration. The advantage of this method was that the amplitude of the forks could be controlled by varying the amount of current passing through the fork magnets. In this way it was hoped that the amplitude of the generating forks could be made great enough to give alternating currents of sufficient strength to secure a strong tone in the telephone resonator. The phase in which the different forks were vibrating could be controlled by shifting the contact brushes by variable sectors.

Great difficulty was encountered in the use of the type of synchronizing motor being used. It was found difficult to adjust the driving current so that the motor would run continuously. Slight variations in the current, variation in the friction from temperature changes or irregularities in the lubrication, were enough to throw it out of step with the regulating fork. All the indications seemed to be that this type of motor was too weak to drive the copper disk properly, the area of which was so great that air friction could be expected to have considerable retarding effect. However, even under favorable conditions of driving, the fork generators were too weak to give strong tones in the telephone resonator. Even during those rare occasions when the motor ran the disk with a regularity and smoothness beyond all criticism, the tones were too weak.

Instead of seeing that the difficulty was in the telephone principle we thought it was due to the fact that the alternating currents which were produced by the generating forks were too weak. We then took a large heavy 150 fork and made a new generating fork which was wound with much finer wire and consequently a larger number of turns. The magnet which drove the fork was also very efficient, giving an amplitude to the fork prongs as high as 6 mm. This was greater than we had ever secured before and much greater than we could hope to secure with the higher forks. Now there should have been no question about the efficiency of the generating fork. We were able to send very strong currents through the inducing coils, but all we got out of the telephone resonator was a beautiful tone as long as the intensity was very low, but as the current was increased the tone became a loud snarl. At this point we should have realized that the difficulty was with the telephone resonator—but the good tones which we secured at low intensities prevented our seeing that a device which gives a pure weak tone need not necessarily give a pure strong tone. Again the blame was equally distributed between the generating forks and the motor.

We thought that the differences in potential were not great enough in the generating coils during one complete cycle of the fork. This difference in potential depends upon the amplitude of the fork; the greater the amplitude, the greater the difference in potential. The amplitude of the experimental fork we were using was, however, so much greater than we could use in the actual experiment on tone intensities, that we decided to use some other principle of getting a greater difference in potential. Accordingly we gave up the fork generator idea and began to develop the microphone principle.

Cylindrical resonators were made for four or five of the forks, which had at their bottoms a carbon telephone disphram placed against carbon granules. When the vibrating tuning fork was held to the mouth of the resonator, the air vibrations within the resonators transmitted their energy to the diaphram and set it into forced vibration. These vibrations changed the electrical resistance between the carbon granules and changed a constant current which was passing, into a varying current. This was then sent through the telephone resonator. Again it was found that the tones in the telephone resonator were too weak and not pure. For the lower intensities the system worked well, but for high intensities the tone became impure and scratchy. Toward the end we used currents which were so strong that the carbon disks and granules became so hot that the paraffin with which they were fastened, began to melt. But increasing the current did not increase the tone intensity to an appreciable extent.

The telephone idea was finally given up after many changes and modifications because a tone which was pure and strong enough to suit our requirements, was not secured.

The next step was to connect the prongs of the forks with diaphragms at the back of resonators.[3] The back of the resonator was made of a mica diaphragm. One end of a light wooden rod was attached to the diaphragm with sealing wax and the other end was attached to one of the prongs of the fork. This gave pure strong tones but they could not be started and stopped quickly. Overtones due to the mica disk appeared when the tones were very strong, but the results were more promising than anything that had been achieved thus far. It was decided to go ahead and devise a method by which the tones could be started and stopped quickly.

The Victor Talking Machine Company of Camden, N. J., very kindly sent us the sound transmitting parts of one of their talking machines. The needle of the sound box was allowed to rest on a piece of wood which had been attached to the prong of the tuning fork. The fork was kept vibrating continually and the tone was started and stopped by raising and lowering the needle on to the piece of wood. For low intensities the tone was good, but at the instant of dropping the needle on the fork a fearful racket was generated. The weight of the needle and the sound box also dampened the vibrations of the fork to such an extent that the tone became very weak and unsteady.

While these experiments with the source of sound were being conducted, the system for driving the forks was being perfected. The original synchronous motor being found too weak, work on a more powerful motor of the same type was started. While at work on this motor, the Leeds & Northrup Co., of Philadelphia, placed upon the market a constant speed device which seemed more promising.[4] What follows is a description of the apparatus finally used.

---

[3] This principle has been used successfully by A. G. Webster in his experiments on tone intensity standards.

[4] We did not buy the complete Leeds & Northrup apparatus but only the converter, rheostat and transformer because we did not think that the regulating fork as they had it mounted would give us the constancy of angular

2. Final Apparatus

The essential parts of the Leeds & Northrup constant speed motor are a regulating tuning fork and a rotary converter which is driven from the direct current side. The alternating current which is generated is treated by the regulating fork in the following manner: The fork is equipped with a second contact point (different from the one which serves the driving of the fork) which opens and closes the alternating current circuit of the converter, with a frequency corresponding to its own period.

The nature of the alternating current is such that it fluctuates in its intensity from zero to either the negative or positive maximum twice during every cycle of the alternating current coils. That is, if the alternating current is of the 60 cycle type, in every second there are 60 instants at which the current strength is at its positive maximum and 60 instants at which it is at its negative maximum. This principle is made use of in the form of a variable load to control the speed of the converter.[5]

The advantage of this system lies primarily in the fact that it furnishes considerable power and is not so limited as that of the type of motor which we used at first, where the current driving the motor must pass through the vibrating contact point, producing a big spark; whereas in this type, only the *regulating load* current sparks, the current *driving* the motor being continuous.

When the load used is in the form of lights, these furnish a visual index of the converter action and a means of regulating the driving current, so that the system will operate efficiently. The operator of the system soon learns to interpret the character of the lights and the noises which are made by the apparatus. It should be noted whether the converter is rotating in the

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velocit [illegible] which is necessary to drive tuning forks by our [illegible] Such disks with their contact springs require [illegible] regulating load is therefore relatively great. T[illegible] fork has a double contact on metal which [illegible] found [illegible] because slight adjustments [illegible] ting [illegible] to make frequent retuning

[5] [illegible] nde[illegible] r Apparatus.

proper direction for getting the best contact conditions for the direct current carbons. If it is necessary to change the direction of the converter as received from the manufacturer, this is readily done by exchanging the terminals of the two lower direct current carbons.

3. Details of Apparatus Parts

A. Batteries

The laboratory is supplied with direct current from the power house at 110 volts and it was at first thought that this would be steady enough in its voltage to run the rotary converter without installing storage batteries. It was found, however, that the changes in voltage due to the turning on and off of light clusters and machinery on the campus, made the current too irregular to work satisfactorily. While the voltage is in general kept up to 110 volts at the power house by suitable regulating devices, yet the apparatus used in this experiment is considerably more sensitive and responds more promptly to changes than the devices used at the generating plant. At times during the day and especially late at night after the offices and halls on the campus are closed, the power house current becomes steady enough to run the entire apparatus.

While the batteries are expensive to install and require some skill in keeping them properly charged, the steady character of the current justifies the expense.

After the batteries had been set up they were used to run the converter only. The regulating fork and tone forks were driven from the power house line. However, double-throw switches were installed at numerous points so that any part of the system could be operated on either power house or battery service. This was of considerable advantage at first since it was easy to determine whether any trouble which developed was due to the character of the current or to the faults in the mechanical construction. It was found that flexibility, as represented by adjustable rheostats and numerous switches, was a great help in locating difficulties and unifying the operation of the system.

To secure the required voltage and capacity from the batteries, 60 chloride accumulator cells, type C T, plates 5 x 5 inches, were bought from the Electric Storage Battery Company of Philadelphia. These were set up as shown in fig. 1. When fully charged and connected in series, they delivered a current of about 120 volts, 3 to 4 amperes, for about two hours. Since the power house current is only 105 volts, the 60 cells are not charged while connected in series but are divided into three units (I, II, III, fig. 1) of 20 cells each.

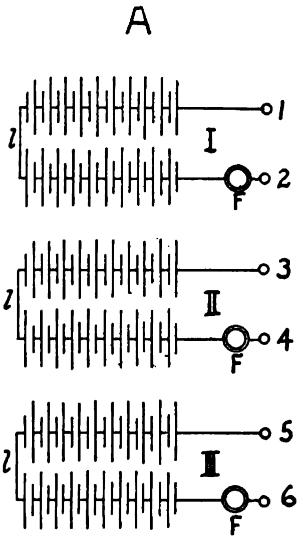

Fig. I

A. Batteries—showing manner of connection.

To save space and also allow for subsequent changes in the grouping, if this should prove desirable, each unit is divided into two sets of ten cells each, connected by a lead strip (*l*).

When batteries are charged in a form of connection different from the one in which they are discharged, there is considerable danger from short circuits being accidentally made when changing the connections from charge to discharge. To avoid seriously injuring the batteries in this way, a switch board (fig. 2) was made which simplified the manipulation of the batteries and avoided accidental damage. In fig. 1 the numbers

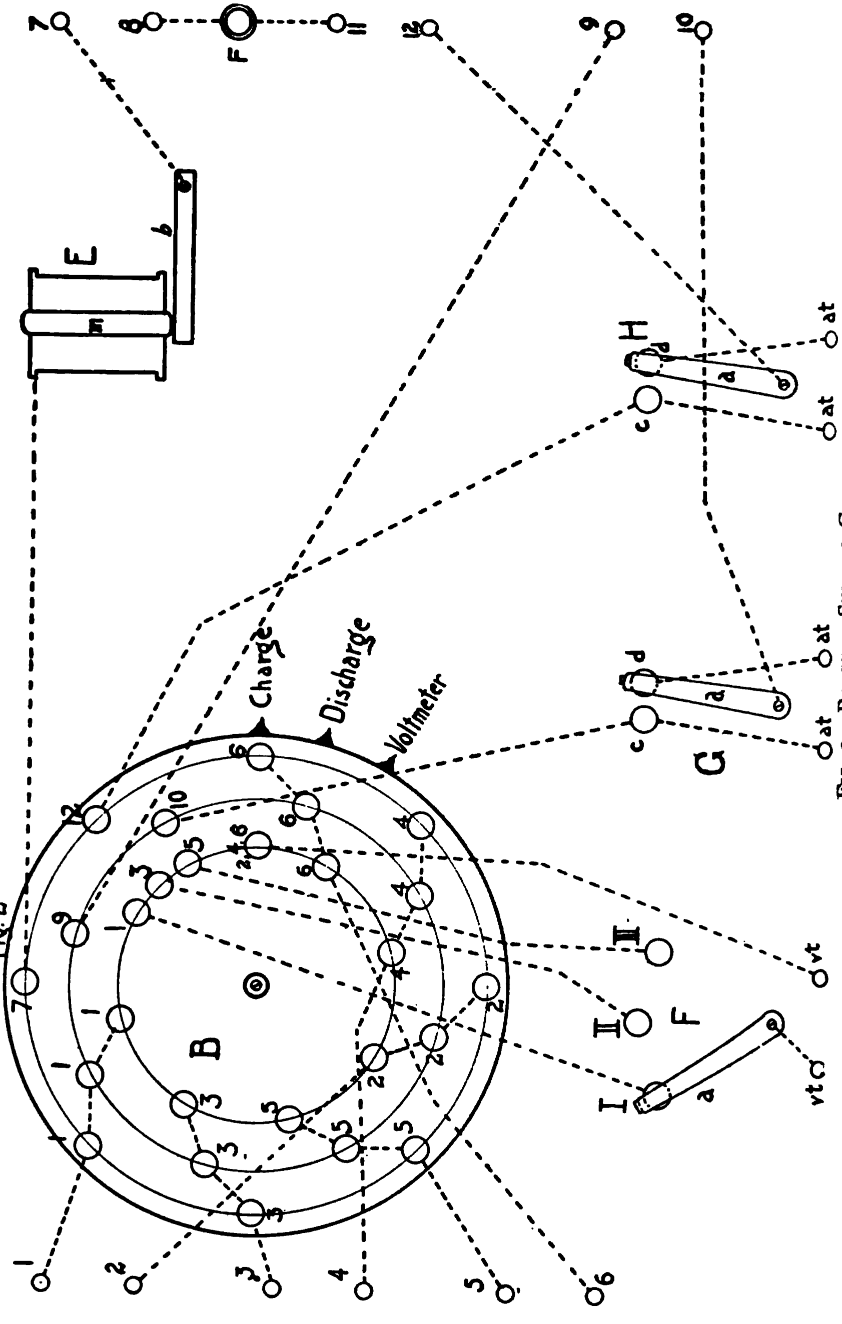

FIG. 2. BATTERY SWITCH CONNECTIONS.

from 1 to 6 are the terminals of the wires which come from the various end plates of the batteries and which end in the correspondingly numbered binding posts on fig. 2. The way in which these terminals are distributed over the switch board can be traced along the dotted lines leading from the terminals. All terminals having the same numbers are connected to the same wires. It is desirable and a saving of time if the testing of the voltage of the batteries and the measuring of the charge and discharge currents can be quickly and easily performed and it was for this purpose that the switch board was designed. The batteries, if properly handled, will last a long time but where it is necessary to make frequent changes of the connections, short circuits and accidents are bound to occur which will quickly injure the batteries unless such accidents are forestalled by automatic devices.

To simplify the battery end of the apparatus, the devices shown by drawings B, E, F, G, H, fig. 2, and C, D, fig. 3, were added. Their use and manner of construction will be explained under the proper headings.

B. Fig. 2. Switch board for making Battery connections.

This drawing shows only the lower connections. Over B is placed the dial-like disk C in fig. 3. The circles inside of B represent the heads of copper belt rivets (r fig. 3, D) which are driven through the wood base of the switch board and fastened by the copper washer (e). The rivets are arranged in three circles divided into sectors of 15 degrees. The rivet heads are spaced in such a way that their centers pass through the radii of these sectors.

C. Fig. 3. Battery Switch Detail

This is the top dial which shifts over the connections indicated in B. It is made of wood, half-inch thick and fastened to B by the screw in the center. B and C are to be regarded as a number of switches combined in such a way that a single shift of C will make and break a whole series of connections. Thus when C is set at "Charge" the battery terminals will be connected to the power house line ready for charging; the automatic circuit breaker E will operate; and the switch H will make it

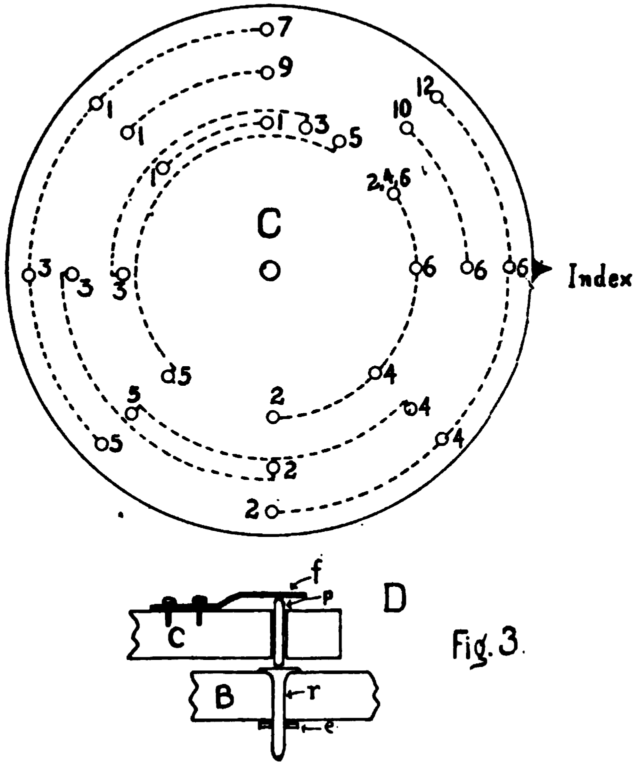

Fig. 3.

C. Upper Dial of Battery Switch.
D. Form of connection between Band C.

possible to read the amount of current which is passing. When C is set at "Discharge" all the above connections are broken. The batteries are now connected in series instead of in parallel and the switch G, for reading the amperage of the discharging current, is thrown in.

When C is set at "Voltmeter" the switch F is thrown in so that the voltages of the battery units I, II, III, can be read successively. The details of the contact construction are drawn in D, fig. 3. Contact is made through the pins (p) one inch long cut from No. 8 copper wire. These pins pass loosely through holes drilled in C and are held in contact with the base B by bronze springs (f). The electrical connections indicated by the dotted lines on C are made through these springs. The springs are flat ¼ x 1½ inches and cut from No. 29 sheet bronze, screwed into the wood by wood screws. When the pin (p) is not resting on the rivet (r) it runs on the wood base and is, of course, insulated from the set of connections which is in operation at the time.

To illustrate: When C is set at "Charge" the path of the current is from the terminal 7, of the power house line; through E to terminal rivet 7 on B; from here it passes through the pin 7 on C into the bronze contact spring; into wire indicated by dotted line to springs 1, 3, 5; into rivets 1, 3, 5, to battery terminals 1, 3, 5; through the batteries in parallel to battery terminals 2, 4, 6, on B; to rivets 2, 4, 6; through pins 2, 4, 6, on C; to pin 12 where the three branches are again united; to switch H; to rheostat between 11 and 12; and finally to the other power house terminal 8.

D. Fig. 3. Drawing showing the details of the connections between B and C

E. Fig. 2. Automatic Circuit Breaker

It often happens that the current supply from the power house is shut off temporarily while the batteries are being charged. The batteries will then discharge through the line and into any machinery or lamps which might have been turned on before the line current was shut off, if there is no device for disconnecting the batteries from the line. The current which is used to charge the batteries comes in through 7, passes through the iron bar (b) into the magnet core (m) and into the coil of the magnet. From here it passes to the switch board B and C. If for any reason there is a break in the charging current, (m) is no longer magnetic and the bar (b) is pulled away from the core (m) leaving the circuit open. This device is especially necessary if the batteries are charged at night and with the current on for only a part of the night.

F. Fig. 2. Battery Voltage Switch

This switch is for reading the voltages of the battery sets I, II, III. The voltages of the different sets are read independently. C is set to "Voltmeter" and the connections for reading the voltages are thus made ready. By moving arm (a) to I, the voltage may be read for the set of batteries I; arm to II, gives the voltage of set II, etc. The voltmeter is connected to the terminal (vt) and should read up to 50 volts. The voltmeter may be set up at any convenient point, or removed for making measurements elsewhere, without disturbing the system. The voltmeter is not shown in the drawing.

G. Fig. 2. Battery Amperage Switch

This switch is for reading the amperage of the discharge or battery current. It is arranged so that an ammeter (not shown) and connected to the terminals (a, t) can be thrown in or out without interrupting the current and without causing a spark. When the arm (a) is shifted to lie on (c) the current passes from (c) through (a) and then directly to 10. In this setting the ammeter is thrown out and may be removed by disconnecting at (a, t). This is of advantage when it is desirable to use the ammeter for other purposes. When arm (a) is shifted to (d) the current passes from (c) to (a, t) through the ammeter; then to (d); then to (a) and then to 10. By placing (c) and (d) so near together that when arm (a) is shifted from one position to the other, there is an instant during which the arm is in contact with both (c) and (d), no spark will result when shifting. The ammeter should read to at least five amperes. This switch operates when C is set at "discharge."

H. Fig. 2. Charging Amperage Switch

This switch is for reading amperage of charging current when connected to batteries. Its construction is practically the same as that of G, but operates only when C is set at "Charge."

J. Fig. 4. Double-throw Sliding Switch

When this switch is set as shown in the drawing, the power house current from 7 passes through the interrupter disks V to magnets of tone forks W, through resistance L and milliammeter M back to terminal 8 of the power house line. When set at (c) the power house current is shut off and the battery current from 9 to 10 passes over the same circuit.

K. Fig. 4. Double-throw Sliding Switch

This switch is of the same pattern as J except that it controls the current for the rotary converter R. When the switch is set

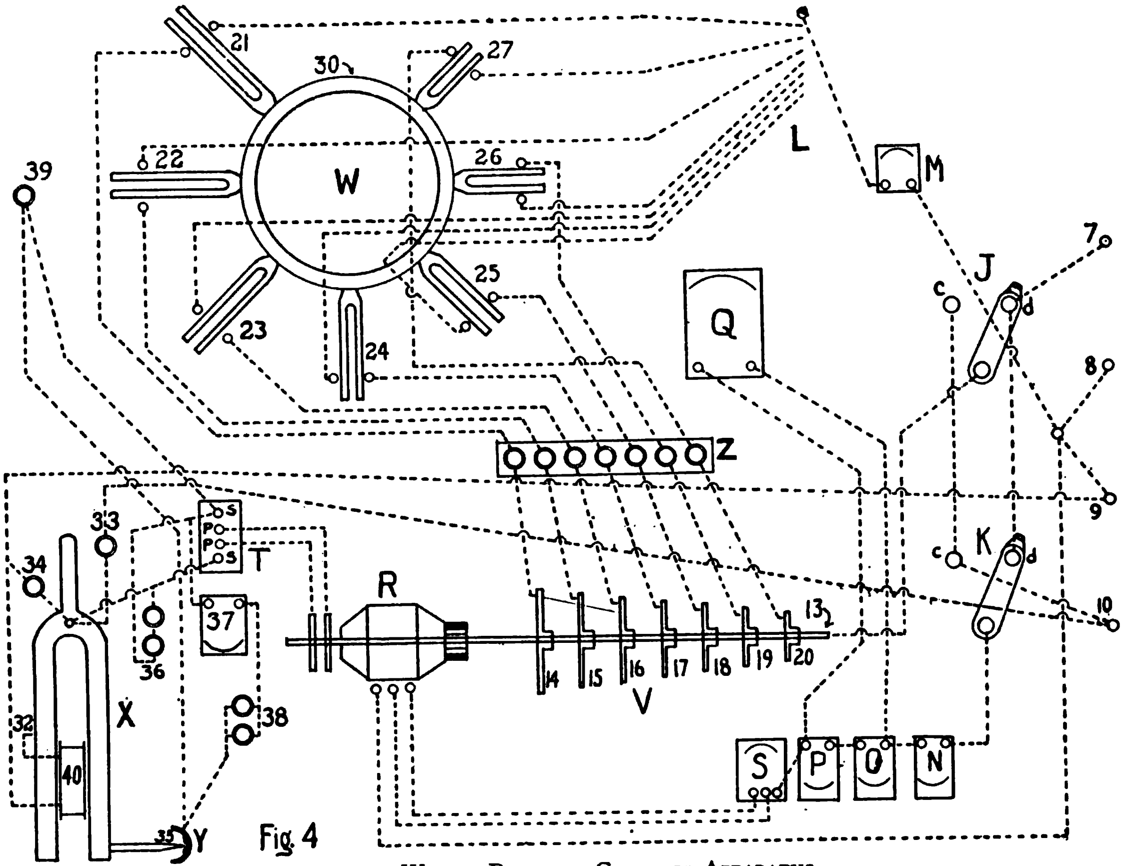

Fig. 4

WIRING PLAN FOR COMPLETE APPARATUS.

at (d), the converter is driven by the power house current 7 and 8; when set at (c) it is driven by the batteries through 9 and 10.

L. Fig. 4. Special Resistance Board

It is desirable to have control of the current passing through the magnets of the tone forks W and preferably of each fork separately. However, a special resistance for each tone fork circuit requires more resistance boards than are usually available. A simple resistance board was made as follows: Between a board running around the base of the room and another board five feet from the floor, about 300 feet of No. 22 iron wire were zigzagged between nails about two inches apart. At the end of the wire coming from the fork, about an inch of tightly coiled brass spring was soldered. This coil serves instead of a binding post in that it can be pinched easily onto any of the nails over which the iron resistance wire is strung. To vary the resistance of the different forks it is only necessary to pinch the coiled springs on the wires coming from each fork, at different distances from the end of the resistance wire. By this method one resistance board will do for all the tone forks.

M. Fig. 4. Tone Fork Milliammeter

This is a Weston Milliammeter, Model 1, reading up to 300 milliamperes. Its use is primarily to indicate variations in the current passing through the magnets of the tone forks W. A resistance board placed between L and M makes it possible to regulate the resistance of the tone fork circuit as a whole so that any changes in the current strength may be compensated. The individual forks are regulated by the board L, but when running from the batteries the voltage gradually drops and it is desirable to regulate the system as a whole. This is done by keeping the milliammeter readings constant by the use of the resistance board between L and M. The Milliammeter is scaled to two milliamperes and even very slight fluctuations in the current strength are readily noticed. Slight variations up to 10 milliamperes make no appreciable difference in the amplitude of the tone forks, and the milliammeter makes it possible to make much finer adjustments than this.

N. Fig. 4. Resistance Board

Ward-Leonard Electric Company, Bronxville, N. Y., No. 443A Wire Dimmer for 12-30, 16 c. p., 110 volt, 50 watt lamps. This is only for coarse adjustment for the rotary converter.

O. Fig. 4. Resistance Board

This board serves the rotary converter R and contains 20 feet of No. 22 iron wire. There are 12 contact points and this means that twelve different changes in current strength can be secured. The type of connection is through copper rivets and a sheet brass arm which moves over the heads of the rivets. Sparking is avoided by placing the rivets so close together that the sliding contact arm is, for an instant, in contact with two rivets. The same principle is described in Switch G.

P. Fig. 4. Resistance Board

This board is of the same type as O and contains 24 feet of No. 18 iron wire distributed over 16 contacts.

Q. Fig. 4. Resistance Board

This board is of the same type as O and contains 100 feet of No. 20 iron wire distributed over 26 contacts. It is located in the experimental room and enables the operator to control the converter from the room in which the tone forks are located, without going into the converter room.

R. Fig. 4. Rotary Converter

Holtzer Cabot Electric Company, Boston, Mass., Type O. D., Size 1, 500 watt, volts 115/75, amperes 7.5, speed 1750 r. p. m., compound wound. This converter is driven by direct current and it generates alternating current which is used as a regulating load. The principle involved was described under Final Apparatus. The rotary converter serves as a motor driving the interrupter disks V through the direct connected shaft 13.

S. Fig. 4. Starting Box

Cutler-Hammer Manufacturing Company, Milwaukee, Wis., 1 h. p., 110/125 volts. This is a standard starting box arranged so that the converter is started gradually. It has an automatic circuit breaker which will break the circuit if for any reason the source of current supply is broken.

T. Fig. 4. Alternating Current Transformer

Holtzer Cabot Electric Company, Boston, Mass. Primary volts 75; secondary volts 220. Primary amperes 7.3; secondary amperes 2.3. Frequency 60. This transformer serves a double purpose. First, by having a higher voltage, the amperes of the alternating current are decreased and the heating effect of the spark made by the regulating fork X is reduced; Second, it prevents the direct current by which the regulating fork is driven from passing into the coils of the alternating current end of the converter; (s) and (p) refer to the secondary and primary coil terminals of the transformer.

V. Fig. 4. Interrupter Disks

These disks were made by Max Kohl, Chemnitz, Germany, from drawings furnished to him. They are made of brass into which have been inserted into round holes, hard rubber plugs which break a direct current which is passing from the disk into a contact spring, every time one of the rubber plugs passes beneath the spring. The number of interruptions will depend on the number of hard rubber plugs and the speed of the disk.

The surface upon which the contact spring slides is ground smooth and the diameters of the rubber plugs have been selected in such a way so that they are equal to the space between the plugs. When the contact spring is so set that it will make contact with the disk at the center of the plugs, the duration of the time during which current is passing through the magnets of the tone forks is approximately the same as when the circuit is open. These disks are mounted on the axle 13 which is driven by the converter R.

The springs through which electrical contact is made are of No. 30 sheet bronze, one-fourth inch wide and screwed to wood supports as shown in the photograph of the converter room.

Nos. 14, 15, 16, 17, 18, 19, 20, are the disks making 450, 400, 350, 300, 250, 200, 150, interruptions per second respectively, when the converter R is running at 1500 r. p. m. or 25 revolutions per second.

W. Fig. 4. Tone Fork Frame

This is located in the experimental room and consists of a heavy cast iron ring 30, one and one-fourth inches thick, three and one-fourth inches wide and ten inches inside diameter. On this the tone forks 21, 22, 23, 24, 25, 26, 27, are mounted as shown in the photograph, by drilling holes into the ring and fastening the forks into these holes. The metal of the fork must not come in direct contact with the metal of the ring, or secondary tones and noises will result. To avoid this the feet of the forks are wrapped in felt sleeves and the washers and nuts by which the forks are fastened into the ring have felt washers placed between them and the metal.

The ring 30 is suspended from the ceiling by a rope and pulley which allows the frame to be lowered to a convenient height for making observations. This mode of mounting also permits the forks to vibrate with great amplitudes without giving a tone unless the resonators are placed near them. Above the forks the resonators are placed which produce the tones. The distance of the resonators from the forks can be read off on a millimeter scale and in this way the intensity of the tone is measured. The resonators are shown in the photograph of the Experimental Room by the numbers 21 to 27. They have been tuned to the same periods as their respective forks. The vibration rates of these forks are 150, 200, 250, 300, 350, 400, 450. The intermittent currents produced by the interrupter disks V pass through the magnets of these forks. When running properly the period of the interruptions coincides with that of the forks in the sense that the fork magnets attract the prongs of the tuning fork only at those instants when the prongs are moving toward the magnet. In this way the vibrations are maintained. The amplitude of these vibrations is controlled by the resistances L and Z.

X. Fig. 4. Regulating Fork

This is a fork made by Edelmann, Munich, having a period which can be varied from 36 to 55 vibrations per second by means of sliding weights. It is electrically driven through the contact 32. Its amplitude is controlled by the 4 c. p. carbon lamp 33. To reduce the spark at the gap 32, another 4 c. p. carbon lamp 34 is placed across the spark gap and coil. The magnet 40 should be made as large and efficient as possible. Upon the constancy of this fork will depend the constancy of the whole system.

While for ordinary purposes the period of a fork can be considered to be independent of the amplitude, this is actually not the case with a magnetically driven fork. The variation of period is, of course, not very great but when all the tone forks are tuned to synchronize with the regulating fork, the slightest variation will influence the tone forks very materially. The variation in the regulating fork is multiplied when it reaches the tone forks. If the period of the regulating fork is changed .2 of a vibration per second from the regular period, this will amount to a whole vibration per second for the tone fork 250. This means that the electrical impulses which reach the tone fork 250 actually have the period 251 and that there is a complete reversal in the phase of the magnetic attraction of the fork prongs every second. This is sufficient to practically silence the fork 250.

The manner in which the regulating fork operates is as follows: the current generated by the alternating current end of the converter passes into the primary coils of the transformer T. The alternating current which is induced in the secondary coils passes into the fork and is interrupted at the mercury contact 35. The alternating current does not pass through the magnet which drives the fork.

During each revolution of the converter, the alternating current passes through two maxima and minima of current strength. If the fork closes the circuit when the phase of the alternating current is at its minimum strength, no load will be thrown on the converter. If the regulating fork closes the circuit at the instant when the alternating current phase is at its maximum, either negative or positive, a heavy load will be thrown on the converter which will retard its speed. If the driving current of the converter is so adjusted that it is just barely stronger than necessary to make the alternations of the converter coincide in period with the vibrations of the regulating fork, the alternations of the converter will tend to overtake the vibrations of the fork.

They cannot, however, advance very much because the magnitude of the alternating current load grows rapidly stronger as the phase of the alternations advances over the period of the fork. As a result the converter will "hunt" a point at which the load is just sufficient to keep the converter in step with the fork. The magnitude of the load which is used to regulate the speed of the converter, is controlled by the resistances, 36, 37, 38. A constant load 36 made of two 8 c. p. carbon lamps is introduced to dampen the spark formed at 35 and to reduce its heat and size. They also serve as visual indicators as to whether the carbons at the alternating current end of the converter are making continuous contact. The light should burn without a flicker even when the converter is not in step with the regulating fork. If the lights flicker jerkily this means that the carbons are not making good contact on the collector rings, and need to be sand-papered or adjusted.

As we are at present using the fork, it is regulating only half the number of times that it might regulate. If we had a contact point on each prong of the fork the vibrations of the fork would correspond to half cycles of the alternating current. With the fork equipped with two contact points and running in step with the alternating current cycles, if one contact comes at the positive maximum the other will come at the negative maximum. If one of the contacts is at zero the other will be at zero. As we have it now, the fork makes contact only at such parts of the alternating current cycle which are of the same sign. Notwithstanding this apparent loss in not utilizing all the regulating capacity of the fork, my experience has shown that it still works better with a single contact point in mercury than with two contact points on opposite sides of the same prong which then necessarily must act on solid metal.[6] This is probably due to the fact that the interruptions at the spark gap are more complete, thus bringing about a greater difference in potential. The alternating current load actually lasts longer than the instants during which the contact point is dipping into the mercury, due to the cohesion of the mercury to the contact point after contact is once made, and especially to the conductivity of the spark gap itself caused by the ionization of the gases and oil.

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[6] I have not tried using a contact on each prong, both contacts dipping into mercury. Thus far it has not been found necessary, but with sounding forks of considerably higher frequency than those we have been using (say above 500 double vibrations) it may be advisable to do so.

With a double contact on solid metal and the ***maximal effective*** distance of the contact points then reduced to one-half of the amplitude of the fork, the load may be prolonged to nearly half a cycle so that any change in the speed of the generator would no longer be accompanied by a change in load.

In the alternating current circuit which passes through the mercury contact at 35, there is a resistance board 37 made up of 120 feet of No. 27 German silver wire, distributed over 24 contacts. After the apparatus was running properly it was found that a constant resistance of two 16 c. p. carbon lamps at 38 was sufficient, and the resistance 37 was then taken out and used to regulate the general resistance of the tone forks between L and M.

A 4 c. p. carbon lamp 39 is placed in the experimental room and enables the experimenter to determine whether the converter is running properly. When this lamp fluctuates in brightness, the converter is running out of step with the regulating fork. When it burns brightly this means that the alternating current load is stronger than necessary. The resistance board Q which controls the driving current of the converter being located in the same room, it is easy to regulate the converter from the experimental room. A little practice is necessary to interpret the character of the glow in 39 properly. When the converter is running properly, the lamp 39 will glow dull red and fairly steady. If it goes out entirely this means that there is no regulating load on the converter. If the converter is, nevertheless, in synchronism this means that the driving current is just strong enough to drive the converter in step with the regulating fork. The light is really an index of the conditions at the spark gap 35.

Y. Fig. 5. Mercury Level Regulator

In order that the period of the regulating fork be kept constant from day to day, it is necessary that the extent to which its contact point dips into the mercury remain constant. This would be a simple matter if the mercury were not splashed about, but to get the best control it is necessary that the point be blunt so that it will make and break suddenly. Such a point, however, churns up the mercury into an emulsion of coal oil and mercury. If this is not removed it gets between the contact point and the mercury surface and the electrical contact becomes irregular. If the surface of the exposed mercury is too large, the contact of the fork will set up stationary waves. In the nodes of these waves the mercury emulsion accumulates and gradually crowds around the contact point.

If the mercury surface is made so small that no stationary waves will form, the emulsion will be thrown off but the level of the mercury will change so rapidly that the period of the regulating fork may change sufficiently during an experimental series to require a retuning of the tone forks. A limited amount of the emulsion is a good thing because it reduces the splashing of the mercury, but unless the excess is constantly and automatically removed, contact difficulties and change in period of the regulating fork will appear.

The device drawn in figure 5 automatically takes care of the mercury level and the amount of the emulsion.

The cup into which the contact point of the fork dips is shown at 35. Its shape is as indicated,—a shallow cup into which the mercury is fed through the passage indicated by the stippling. At (b) and (c) are upright tubes communicating with each other and the mercury cup 35. The mercury is added to the tube (c) from the reservoir of mercury at (r). The tube (b) carries an iron weight (w) which floats on the mercury. Any change in the level of the mercury in the cup 35 will either raise or lower the weight (w). To this weight is attached a fine wire (d) which acts on the light bronze lever (e). This wire is insulated from (e) by making part of its length out of thread. When the mercury level at 35 is lowered the weight (w) sinks and thus raises the lever (e) until it makes contact with the plate (f). As soon as contact is made at (f) an electric current passes through (e) to (g), then to (h) and through (i) to the coils of the magnet (j) which raises (h) from the contact (g) and

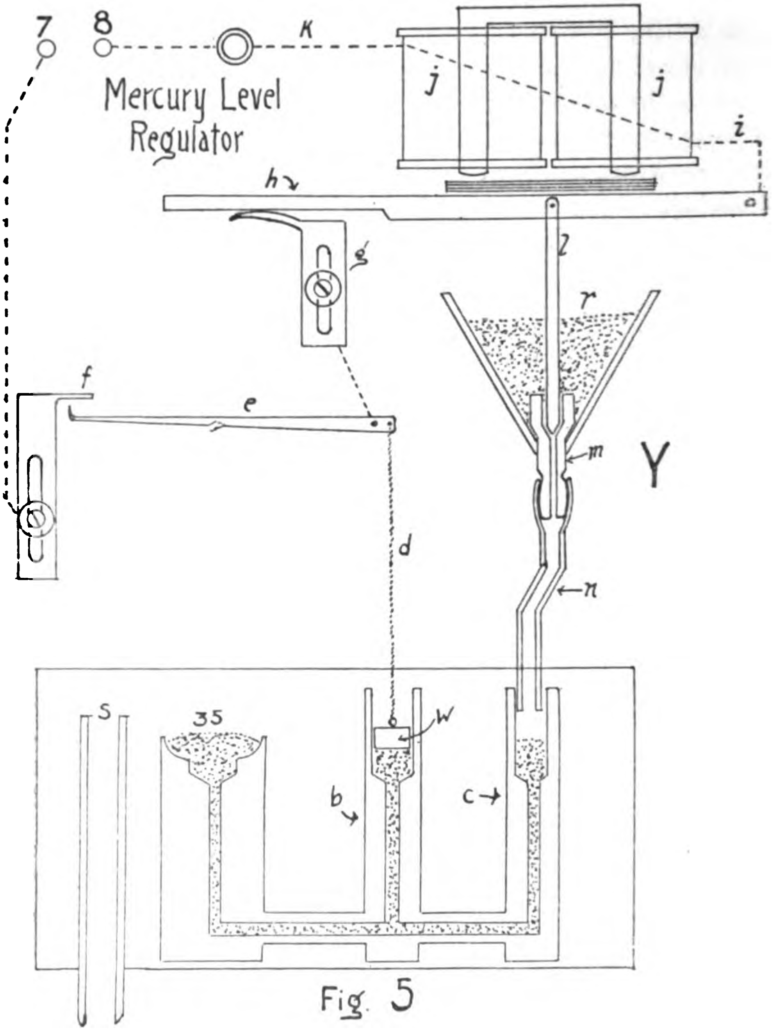

Fig. 5

METHOD BY WHICH THE LEVEL IN THE MERCURY CONTACT CUP WAS MAINTAINED CONSTANT.

breaks the circuit. When (h) drops back to (g) the cycle is repeated for as long a time as (e) is in contact with (f). To the arm (h) is pivoted the needle valve stem (l) which dips into the mercury reservoir and opens and closes the opening in (m). Every time (h) is raised, (l) is raised off the valve seat in (m) and a drop of mercury escapes into the glass tube (n) and into the tube (c). When the mercury droplet reaches (c) it raises the level of (c) and also (b) and of cup 35. When the level of (b) is raised the weight (w) moves upward and in so doing the lever (e) is depressed and the connection between (e) and (f) broken. All of this happens much more quickly than can be described.

The sensitivity of the change in level will depend upon the relative lengths of the lever arms in (e). In the apparatus under discussion, the relation is about 1 to 20 and the break between (f) and (e) is rarely more than a millimeter. This represents a change in the level of the mercury of about .05 mm., a change so small that it cannot be detected in the load circuit.

After a drop of mercury has been added and the contact between (e) and (f) is broken, the excess of emulsion formed at 35 is gradually thrown over the rim of the cup and collects in the bottom of the tank where it lies until a considerable amount has collected. This emulsion has a large percentage of mercury in it which can be reclaimed by gradually drying the emulsion over a radiator or gentle source of heat.

All parts which come into contact with either the mercury or the emulsion are made of iron or glass as mercury forms an amalgam with most of the metals found in the laboratory.

The tank into which the mercury cup is placed is made of sheet iron and the tubes (b, c, 35) are kept in place by being imbedded in plaster of paris.

During operation the tank is filled with running coal oil to prevent heating and oxidation of the contact metals (iron and mercury) at 35. This oil drains off through the tube (s) into a collecting vessel. The top of the tube (s) is threaded and has a pipe coupling loosely screwed on so that the level at which the oil stands can be easily varied. The oil which drains off is rather dirty and has a considerable amount of free carbon in suspension. This is due to the electric spark at 35 which decomposes the coal oil. Before being used again the oil is run through the sand filter shown in the photograph, where these impurities are filtered out.

The plate (f) is made of bronze and is grooved so that it can be moved up and down for adjustment. The height of the mercury level is regulated at this plate before an experiment or series of experiments is begun. If the iron contact point does not dip into the mercury enough, the regulating load is too small. If the iron point dips in too much the load is so great that the variations in the load are too small. The mercury level is so adjusted by moving the plate up or down that when the motor is in synchronism with the regulating fork the filaments of the carbon lamps 38 glow a cherry red. After the level of (f) has been adjusted the device will maintain the mercury level at a constant distance from the iron point for many days or even weeks, until an appreciable amount of the iron point has been consumed by the spark.[7]

Z. Fig. 4. Lamp Resistance for Tone Forks

This is an ordinary lamp bank except that the lamps are not connected in parallel. There is one lamp socket for each fork and since this is only a rough adjustment 4 or 8 c. p. lamps will serve.

Tone Fork Magnets

If the magnets of the tone forks are properly made, they do not require a great deal of current to drive them at the desired amplitude. The current never exceeds one-fourth ampere and one-eighth ampere is usually sufficient. The magnets should be as wide as the spread of the forks will permit. The iron core should be heavy, at least one-half inch in diameter and the diameter of the coil should not be less than two inches. The wire used should be about No. 30 magnet wire, wound carefully so as not to get short circuits. Lamps alone are hardly a fine enough adjustment, for controlling the amplitudes of the forks. The finer adjustment is made at the rheostat L.

4. METHOD OF CONTROLLING PHASE

Since the experimental work reported in this paper does not make especial use of the phase relations between the tones used, a complete description and mechanical drawings of this part of the sound intensity apparatus will be given when an experiment in which phase relations play a more important part will have been performed. However, a general outline of how we expected to secure and control any phase relations which we had anticipated might become an object for experimental investigation, may be of interest. The mechanical principles which we expected to use were the following.

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[7] The mercury cup in the photograph showing the Regulating Fork is only a preliminary cup which was used before the mercury level regulator had been completed.

1. The interrupter disks, when the contacts are once adjusted, give tones whose phase relations remain the same.

2. A moving contact which rotates or oscillates on the face of the interrupter disk.

3. Electro-magnetically controlled shutters which open and close the resonators so that only the particular phase relations which are to be studied are presented.

1. The interrupter disks referred to have been described under V of the Details of Apparatus Parts. In the experiment which follows, it was only necessary to establish the fact that all the forks were vibrating in the same phase. The contacts, as shown in the photograph of the converter room, can only be adjusted so as to increase or decrease the pressure on the disk. The phase was adjusted by loosening the set screw which held the disk onto the shaft and rotating the disk the required amount. To set all the forks in the same phase, the disks were so adjusted that all the resistance lights in series with the magnets of the tone forks (Lamp resistance Z, Fig. 4) lit up simultaneously when the interrupter shaft 13 was slowly moved by hand.

Where it is necessary to change the phase by a measurable amount a finer adjustment was contemplated. The bearing of the shaft 13 has a metal segment of an arc attached to the supports as shown in the photograph. Upon this segment a radial arm (also shown) may be clamped. The arm carries the contact spring and it may be regarded as one of the radii of the segment since they both have their virtual centers in the center of the interrupter shaft.

A micrometer screw arrangement clamps on to the segment and acts on the radial arm. The amount of phase displacement of the contact point is derived from the angular displacement of the contact point. To calculate this, it is necessary to know the pitch of the micrometer screw, the length of the radius at which the screw acts on the radial arm and the number of contacts the disk makes in one complete revolution. Where it is desired to study the phase comparatively, the foregoing degree of adjustment is adequate, but where it is necessary to pass quickly from one phase adjustment to another, or where it is desirable to have one fork slowly changing its phase relative to another fork (floating phase) the manual method of phase displacement should be replaced by some mechanical method.

2. We contemplated doing this as follows: running parallel to the interrupter shaft we have an auxiliary shaft (not shown in photograph) which is driven by the interrupter shaft through a worm (which appears in the photograph as the extreme end of the shaft) and worm-wheel and bevel gears. It rotates at one hundredth the rate of the interrupter shaft. The auxiliary shaft carries an arbor pulley into which may be fastened sprocket wheels of various diameters. These sprocket wheels may be turned of wood with short nails driven into the periphery to act as sprockets for the links of a light driving chain.

A similar arbor pulley to which is fastened a radial arm and contact point, rotates around the interrupter shaft. By selecting the sprocket wheels of the proper diameters, the rotating contact may be made to furnish interruptions for a tone which differs by only a slight fraction of a vibration from the tone which is derived from the disk when the contact is fixed.

Where it is desirable to have only a partial phase displacement an eccentric is attached to the auxiliary shaft and this is connected to the radial arm carrying the contact which will now no longer rotate completely around the disk, but will oscillate back and forth between whatever angular limits the conditions demand. This may be used to study the critical points in a sound wave[8] (inflection points, relative maxima and minima of compound waves, etc.).

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[8] The credit for the recognition of the need of sound experiments with controlled phase is Dr. Meyer's who has long been interested in determining experimentally whether we hear all that a Fourier analysis of a compound sound wave reveals, or whether we hear more, or what it does not reveal.

3. In order to make it possible to present the tones for observation when they are at exactly the phase relations desired, an electro-magnetic control of the resonator shutters was contemplated. This control was to originate from contacts suitably disposed on the auxiliary shaft. In this connection it may be well to draw attention to the fact that the auxiliary shaft is well adapted to chronoscopic functions by which the tones may be presented in any order. As already indicated the ratio of the revolutions between the interrupter shaft and the auxiliary shaft is as 1 : 100. The interrupter shaft rotates at the rate of 25 revolutions per second which gives the auxiliary shaft one revolution in four seconds.

By means of toothed wheels whose teeth are spaced to produce the required duration and alternation of the intervals, the times at which the various shutters of the resonators are opened and closed may be compounded into almost any kind of a series. Another advantage lies in the fact that the timing device is always in synchronism with the sound producing system.

II. EXPERIMENTS ON THE RELATIVE INTENSITY OF SUCCESSIVE, SIMULTANEOUS, ASCENDING AND DESCENDING TONES

What has preceded seems to deal with the physical principles of constant rotation and of tone production rather than with the psychological properties of tones. However, in psychology as in the other sciences the time has passed when it is possible to perform fruitful experiments on new problems with apparatus that was designed for other problems and that is now listed in the catalogs of dealers in psychological apparatus.

When the apparatus had been developed to the point at which it seemed profitable to begin the psychological experiments for which it had been designed, it was decided to begin with the simplest of tone intensity problems. This seemed to be the influence of the method of presentation upon the intensity relations between tones. At the close of the experiment the "simplicity" was decidedly less simple than it appeared to be at the beginning.

The reason why it was necessary to restrict the experiment to the *relative* intensity instead of working with absolute intensities and then from these deriving the relative values, was mainly due to the fact that no absolute standard which could be used was available. The Bureau of Standards at Washington does not furnish a tone of unit intensity which may be used as a standard. Professor A. G. Webster has defined a standard of tone intensity but to calibrate the intensities used in this experiment in terms of this standard would require an interferometer and a degree of technical skill in the manipulation, which would require months to develop. A simpler device is needed. The writer hopes, in the near future, to design an electrically driven fork which may be used as a standard for tone intensities which will be suitable for psychological laboratories and adapted to the needs of psychologists rather than the needs of the physicists. The situation in audition at the present time is similar to the situation which prevailed in vision before photometric measurements had attained the perfection and simplicity which they now possess. Some kind of a standard of tone intensity must be devised. At first, as in vision, this will be some individual's standard but as interest in the subject develops, more fundamental standards will be developed.

1. Historical Setting

The references in the literature to tone intensity are mainly restricted to simple experiments where loud, medium and weak represent the nearest approach toward intensity control.

Such experiments as have been made are rather simple and were performed not to investigate the intensity relations between tones so much as to illustrate some phase of the writer's main thesis, be this in music or some of the other attributes of tones. For this reason no exhaustive attempt will be made, in this paper, to collect the scattered references to tone intensity. Such a task is a problem in itself and one for which the library facilities must be wider than those which are now available to the writer.

The facts which have impressed the writer most in his search through the literature can best be described by a quotation from Lord Rayleigh.[1] "In default of decisive experiments (on tone intensity) we must endeavor to balance the a priori probabilities of the case." Again, "What is most wanted at the present time is a better reckoning of the itensities of the various tones dealt with and observed."

Helmholtz[2] introduces the problem of tone intensity by pointing out that the intensity of a tone increases and diminishes with the amplitude of the oscillations of the sounding body. While numerous references are made to tone intensities throughout his extensive treatise, he did not perform experiments in which the intensities of tones was the cardinal consideration.

Seebeck[3] concluded that when a musical tone was compounded of several simple tones, part of the intensity of the upper constituents went to increase the intensity of the prime tone with which it fused so that at most a small remnant excited in the ear the sensations of an upper partial tone.

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[1] Theory of Sound, vol. II, pp. 461, 469.

[2] Sensations of Tone. Transl. by A. J. Ellis. Second Engl. Edition, p. 10.

[3] Poggendorfs Annalen der Physik. Vol. 60.

Stumpf[4] describes an experiment originally reported by Ohm.[5] When a tone and its octave are simultaneously bowed on a violin and the lower tone is suddenly dropped out, the remaining high tone seems to become stronger, and when the higher tone is dropped out the lower tone becomes noticeably weaker. Seebeck in commenting on the same experiment concludes from this that: tones when present even in considerable intensity can scarcely be heard as soon as the lower harmonic tone is added, but they do add to the intensity of the lower harmonic.

The experiments reported in this paper support Seebeck's law but with the relatively pure tones which were used, the effect is not nearly so pronounced as intimated by Ohm and Seebeck.

2. Statement of the Problem

Since no report on extended experiments in sound intensity is known to the writer, and since all theoretical interpretation of auditory phenomena must eventually consider the intensity relations between sounds, it was thought best to begin with the simple phenomena of tone presentation.

At the present time an experiment in vision which disregarded the facts of adaptation would not be attempted. We know now that the colors and brightnesses which we *shall* see, will depend largely upon the other colors and brightnesses that we *are now* seeing or *have just* seen. By this it is not implied that auditory reactions exhibit adaptation phenomena of the same character as that of vision. We simply know nothing about it. It is, however, important that we should know what to expect when tones are presented in different ways.

Of the various ways in which tones may be presented, four will be made the subject of this experiment.

1. Successive, or alternate tones.
2. Simultaneous, or tones sounding together.
3. Ascending, or varying from weak to strong.
4. Descending, or varying from strong to weak.

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[4] Tonpsychologie. Vol. 1, p. 241.

[5] Poggendorfs Ann. d. Physik. Vol. 47.

From these four methods of presenting tones, four experimental series may be made up as follows:

1. Successive Ascending.
2. Successive Descending.
3. Simultaneous Ascending.
4. Simultaneous Descending.

In investigating the intensity relations presented in this way, it was decided to use the method of Supra-liminal Increments. This method requires a great deal of time and the results cannot be represented so easily nor so clearly as by the method of Right and Wrong cases. However, to use the latter method effectively it is necessary to predict the probable limits within which the phenomena to be investigated will occur. The method of Supra-liminal Increments, thus in this sense is a necessary preliminary step. For this reason it was used in these experiments. To verify, by the method of Right and Wrong cases, the results of this experiment, is the logically following step in the experimental program.

3. METHOD OF EXPERIMENTATION AND OBSERVATION

The tones throughout this experiment are produced by resonators hung over vibrating tuning forks. A guide on which the resonator runs, makes it possible to easily vary the distance between it and the prongs of the fork. A shutter covered with felt runs with the resonator. The shutter moves in a lateral direction and opens and closes the mouth of the resonator, thus starting and stopping the tone. The tone fork vibrates continuously, but being mounted on a rigid frame which is suspended from the ceiling by a rope, it cannot set into vibration any considerable surface of air and as a consequence it remains inaudible at the distance it is placed from the observer.

The resonators are counter-balanced so they will remain at whatever position they are placed. Each resonator may, however, be connected with a little crank in the arm of the chair in which the observer sits, enabling the observer himself to change the position.[6]

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[6] The details may be traced out in the photographs showing the Tone Fork Frame and the Experimental Room.

When resonators are used as a source of sound, the tones seem to be purer than the tones secured from the forks when they are mounted on their own resonance boxes, and they are much purer than when the fork vibrations are conducted to the ears by means of tubes. The intensity of the resonator tone is somewhat illusory in that it seems weak when compared with ordinary sounds such as walking, talking, moving about, which are constantly occurring near class rooms. But when attention is directed to the resonator tone it can easily be discriminated out of a complex of sounds which seem to have a much greater intensity.

The two observers in this experiment were the writer (Obs. A.) and his wife (Obs. B.). Obs. A has worked with tones for a number of years, especially under the conditions found in psychological laboratories. Obs. B. has had some training in the laboratory and in general psychology, and considerable training in music.

It was hoped that a greater number of observers might have been used, but it was necessary to conduct the experiments at night and until the mercury level regulator had been perfected so many interruptions occurred, and series had to be repeated so often that the writer did not feel free to ask other observers to sacrifice their evenings for about a month. Furthermore, making intensity judgments requires a considerable amount of preliminary practice before they become constant enough to use in an experiment such as the one being conducted. Mrs. Weiss and the writer alternated as experimenter and observer. After a short time Mrs. Weiss was able to control the apparatus quite as well as myself.

The writer wishes to state here specifically what has been implied in other places, namely, that this set of experiments is preliminary in character to a more extensive program of sound intensity investigation. When laws are to be merely verified and the probable limits are quite well known, extensive experiments with many observers are necessary, but for problems dealing with the fundamental attributes, intensive rather than extensive experimentation is of greater value at first.

In this experiment the four tones 150, 200, 250, 300, were used. Each of the tones was presented in ten intensities, which ranged from a weak which could be heard easily when sounding alone, to a strong which was, however, not so loud as to be annoying. When a tuning fork tone is very strong it has a sort of "boom" to it which is distracting in intensity judgments. The ten intensities used can be described best by saying that the greatest and weakest intensities were well within the limits of the intensities to which we ordinarily attend. The loudest tone was not particularly loud, nor the weakest tone particularly weak. Between these limits were interpolated eight other intensities, making ten in all.

These intensities were measured on a millimeter scale placed so as to indicate the distance of the mouth of the resonator from the tuning fork prongs. The resonator was so placed that a line passing through the center of the mouth would pass midway between the prongs of the fork, at right angles to the axis of the fork.

In a preliminary series on the limens of intensities, it was found that equal steps on the millimeter scale do not represent equal differences in intensity. This was, of course, expected since the energy of a vibrating system is with approximation inversely proportional to the square of the distance. The scale between the limiting intensities was not divided into eight equal parts, but into eight steps derived from squaring a constant value. Thus, it was decided to take the strongest tone with the 150 resonator at about 15 mm. from the fork; the weakest intensity at about 75 mm. It was necessary to have a series made up of more than ten steps because equal intensities for the different forks are not found at equal distances. In other words when the resonator of fork 150 was at 50 mm. it did not give a tone of the same intensity as when the resonator of fork 300 was at 50 mm. It was desirable that the series be supra-liminal but yet close enough together so that all the intensities between the limiting intensities were represented. Finally the base of the series was chosen as .60. By squaring multiples of .60 a series of logarithmic steps result as follows: .36, 1.44, 3.24, 5.76, 9.00

12.96, etc. After dropping the decimal places the steps decided upon become 6, 9, 13, 18, 23, 29, 36, 44, 52, 61, 71, 81, on the millimeter scale. Of this series any ten adjacent steps will be equal to any other ten adjacent steps.

To convert the intensities of one fork into those of any other fork it is necessary to adjust them subjectively until they seem to be of equal intensity and then select that set of ten steps for each fork which groups, in the same order, around the points of the two millimeter scales found to be equal. It was thought at first that it would be simpler to set the resonators at equal intensities and then adjust the millimeter scales so that the readings on both would be the same. This would mean, however, that the readings did not mean distance of the resonator from the fork.

At this stage of the experiment it was not possible to maintain the intensity of any given fork constant for many days at a time and shifting the millimeter scales from day to day would introduce a group of variable quantities whose correction would be much more difficult than the conversion of the millimeter, to a tone intensity scale. As a matter of fact the ten steps, 13 to 81, were suitable for all the forks except 150 for which the ten steps were 6 to 61. These steps were, of course, arbitrarily chosen at the beginning of the experiment, but the final results shown in table XI show that they were satisfactory.

The method of making the judgments is that of "Selbsteinstellung." The observer sits under the sound frame W in the chair (Ch O) as shown in the Experimental Room photograph. The forks are 24 inches overhead and out of sight. The experimenter sits in the chair (Ch E). He changes the position of the resonator of the constant tone whenever a series has been completed and manipulates the shutters on the resonators. The tripod table (Tr) is used for recording the data. The resonator of the variable fork is adjusetd by the observer by turning the crank (Cr) located in the arm of the chair (Ch O).

It was decided at first to use a head rest and only one ear, but the results were less satisfactory and more variable than when the head is free to move, even though the effect of sound interference by reflected waves was thus a much more disturbing factor. By allowing the head free the *average* conditions were maintained more constant. Unless the head is clamped very rigidly and always exactly in the same position, greater variations result than when free to move. Fatigue and distracted attention also set in more quickly.

The combinations of the tones were twelve in all: 150-200; 200-150; 150-250; 250-150; etc., as shown in the tables. Each combination of two tones was given twice; once with the lower tone at constant intensity, and then again with the higher tone constant. The preliminary work on the intensity scale had given the observers sufficient practice to enable them to make the judgments easily. Considerable difficulty had been anticipated in making the judgments but this difficulty proved to be only temporary. Toward the end of the experiment, even when the tones were an octave apart the experimenter who was recording the results frequently marveled at the constancy of the judgments.

Secondary criteria such as the number of turns made with the crank, were eliminated by frequently altering the length of the cord. The judgments were made in the order, successive-ascending, successive-descending, simultaneous-ascending, simultaneous-descending, until the 40 judgments for each intensity had been made. Each of these four judgments requires a different adjustment and to use secondary criteria, it would be necessary to remember the kinesthetic conditions of the fourth preceding judgment.

The record sheet was in the form of the following table which represents a typical series for Observer A.

Position of constant fork 300.	Position of variable fork 200.			
	Successive		Simultaneous	
	Ascending	Descending	Ascending	Descending
81	84	74	84	75
81	89	88	86	80
81	88	86	101	94
81	95	86	95	85
81	83	82	98	85
81	86	80	91	80
81	85	83	95	81
81	85	82	90	80
81	83	78	92	76
81	90	84	83	83
Median	85	82	91	80

The table shows the results for the fork combination 300-200 for the weakest intensity (1) used. The readings are in millimeters. For the twelve fork combinations, with ten intensities for each combination and for two observers, the total number of tables was 240. Since each table contains 40 judgments or "Einstellungen" the total number of judgments which formed the basis for the conclusions of the experiment was 9600. To secure the median values, as shown in the last line of the table, the readings were arranged on graph paper in order of their magnitude and the value in the fifth place, counting from the lowest, was taken as the median. For example, the values of the successive-ascending series in the table when arranged according to magnitude are 83, 83, 84, 85, *85*, 86, 88, 89, 90, 95. The value in the fifth place is 85 and this is taken as the median.

When the series were compared as shown in tables I to VI the new median (not the average of the two medians) was taken. Thus considering the comparison between the successive-ascending and the simultaneous-ascending series, the twenty values of both these series, arranged in order of magnitude is as follows: 83, 83, 83, 84, 84, 85, 85, 86, 86, *88*, 89, 90, 90, 91, 92, 95, 95, 95, 98, 101. The value found in the tenth position was taken as the median of both series. This value is 88. It happens that the median of both series combined is the same as the average of the two medians taken separately, but this need not be the case. The median of the series taken together was selected because it seemed more likely that this is the value which would have been secured had the two series been presented at random.

By taking the values in the fifth and tenth positions the true median is not found. In a series made up of ten trials the median would be found between the values of the fifth and sixth places, depending on the frequency of the adjacent values. This was considered an unnecessary refinement since all of the series were to be treated in the same way and the comparisons were relative, not absolute.

As already stated, the figures in the table represent millimeters, and in order to convert these millimeters into intensities it is necessary to multiply the derived values from the table by a constant which is different for different distances on the scale. Thus the difference in millimeters between the medians of the successive-ascending and the successive-descending series is 85 — 82 = 3 millimeters. A difference of 3 millimeters when the resonator is at 85 does not produce as great a difference in intensity as a difference of 3 millimeters when the resonator is at 13. In order to correct for this and to convert the differences in millimeters into differences in intensity, each difference in millimeters was multiplied by a constant which depended upon the region on the millimeter scale in which the difference was located.

These constants were determined by taking the reciprocal value of the differences in millimeters between the successive steps. The steps decided upon were at 6, 9, 13, 18, 23, 29, 36, 44, 52, 61, 71, 81, on the millimeter scale. The differences between successive steps are 3, 4, 5, 5, 6, 7, 8, 8, 9, 10, 10, millimeters. The reciprocals of these values are .333, .250, .200, .200, .166, .143, .125, .125, .111, .100, .100. A difference of three millimeters in the region of the scale point 81 would thus be a difference in intensity of 3 × .100 or .3 of an intensity step. A difference of three millimeters in the scale region 25 would make a difference of 3 × .166 or .498 of an intensity step.

In the data never more than two decimal places were retained and the principle according to which decimals were dropped was the usual one of selecting the nearest whole number. In case the decimal to be dropped was 5 the nearest even number was taken. Thus .425 became .42 and .435 became .44. The decimals in all of the tables were reduced in this way.

As an illustration of how these values may be interpreted we will take the value of the variability for all the judgments which was found to be 1.48 steps. This means that when the constant fork resonator was set, for instance at the intensity 6 or at the distance 44 mm., one-half of the intensity judgments of the comparison fork fell within 1.48 intensity steps or 1.48/2 steps on either side of the median. The value .74 is a plus and minus value. To calculate the limits within which one-half of the judgments of the comparison fork will be found when the constant fork was set at 44 mm., it is necessary to divide .74 by the reciprocal value (.143) for this region of the scale. This gives the value 5.1 which now represents millimeters. Using this now as a plus or minus quantity for the scale region 44, we have 44 plus 5.1 and 44 minus 5.1 which roughly gives the values at 49 and 39. Thus 49 and 39 represent the limits on the scale of the comparison fork resonator within which one-half the intensity judgments were found, when the constant fork was set at 44, provided the scales of both forks were the same. If this is not the case, a correction must be made but this does not effect the principle.

The values in the tables which follow are in terms of the ten steps which were used in the experiment. A plus value means that the tone under consideration was made stronger, while a minus sign means that the tone was made weaker to the extent of the steps indicated by the digits. The values of the tables can be converted into percentages of the whole range of intensities used, by moving the decimal point one place to the left. Thus the .74 step which was found to be the measure of the variability for all the intensities is thus changed to .074 which means that one-half the judgments of intensity were found to lie within plus and minus .074 per cent of the total range of intensities. Expressed more concretely, if one tone is held at a constant intensity and another tone is adjusted to the same intensity a large number of times, it will be found that one-half the judgments will lie within .074 of the total range of conveniently obtainable intensities.

4. Results and Conclusions

The tables which follow are in the main self-explanatory. The series which are compared are indicated at the head of the table. The numbers 150, 200, 250, 300, indicate the vibration rates of the four tones used. The results for the various combinations of these tones are found where the vertical and horizontal columns intersect. The tones of the first column were always the ones kept at a constant intensity.

The values below the blank diagonal in the upper table represent the values when the higher tone was the constant tone, and the values above the diagonal—when the lower was the constant tone. The weakest intensity is designated as I and the strongest as 10.

The conclusion which is given is only the most obvious one. Further discussion of the results is taken up later.

The (A) table is derived from the same data as that from which the upper table was derived.

All forks vibrated in the same phase.

SUCCESSIVE ASCENDING
COMPARED WITH
SUCCESSIVE DESCENDING

The table values indicate the intensity steps that were added to the intensity of the Ascending tone, to give the intensity of the Descending tone.

TABLE I

Ten intensities combined. 4800 judgments.

Variable Tones

	150			200			250			300		
Constant Tone	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.
150				1.41	1.16	1.28	.76	.83	.80	1.12	.89	1.00
200	.99	.81	.90				.84	1.02	.93	.80	.81	.80
250	.85	.63	.74	.78	.70	.74				.78	.71	.75
300	.91	.77	.84	.88	.68	.78	.88	.52	.70			

When low tone is the constant tone, average is................ .93
When high tone is the constant tone, average is............... .78
Average for whole table is .... .86

Conclusion:

When compared SUCCESSIVELY with a tone of constant intensity, tones varying from strong to weak (DESCENDING) are made .86 step stronger (or heard .86 step weaker) than tones varying from weak to strong (ASCENDING).

TABLE IA

Ten intensities separate. All combinations taken together.

Intensities

Obs.	1	2	3	4	5	6	7	8	9	10
A	.96	1.00	.75	1.00	1.12	1.00	1.00	1.00	.50	.75
B	.64	.60	1.00	.91	1.12	1.00	.75	.86	.66	.75
Med.	.80	.89	.84	1.00	1.12	1.00	.75	.86	.50	.75

The extent in steps to which the conclusion holds for the separate intensities is indicated in the last line.

SIMULTANEOUS ASCENDING
COMPARED WITH
SIMULTANEOUS DESCENDING

The table values indicate the intensity steps that were added to the intensity of the Ascending tone, to give the intensity of the Descending tone.

TABLE II

Ten intensities combined. 4800 Judgments.

Variable Tones

	150			200			250			300		
Constant Tone	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.
150				.70	1.09	.90	.96	.73	.84	.88	.83	.86
200	.37	.86	.62				1.14	1.56	1.35	1.03	1.02	1.02
250	.94	.67	.82	.81	.96	.88				.73	.55	.64
300	1.05	1.07	1.06	1.06	1.08	1.07	1.02	.73	.88			

When low tone is the constant tone, average is................ .94
When high tone is the constant tone, average is............... .89
Average for the whole table is.............................. .92

Conclusion:

When compared SIMULTANEOUSLY with a tone of constant intensity, tones varying from strong to weak (DESCENDING) are made .92 step stronger (or heard .92 step weaker) than tones varying from weak to strong (ASCENDING).

TABLE IIA

Ten intensities separate. All combinations taken together.

Obs.	Intensities 1	2	3	4	5	6	7	8	9	10
A	1.00	1.20	.91	.87	.84	.84	1.33	.75	.75	1.00
B	.80	.80	.87	1.19	.87	1.00	.84	.75	1.36	1.00
Med.	.84	1.09	.89	.96	.84	.87	1.14	.75	1.00	1.00

The extent in steps to which the conclusion holds for the separate intensities is indicated in the last line.

SUCCESSIVE ASCENDING
COMPARED WITH
SIMULTANEOUS ASCENDING

The table values indicate the intensity steps that were (algebraically) added to the intensity of the Successive tone, to give the intensity of the Simultaneous tone.

TABLE III

Ten intensities combined. 4800 Judgments.

Variable Tones

Constant Tone	150 Obs. A	150 Obs. B	150 Av.	200 Obs. A	200 Obs. B	200 Av.	250 Obs. A	250 Obs. B	250 Av.	300 Obs. A	300 Obs. B	300 Av.
150				–1.46	–.03	–.75	–.91	–.70	–.80	–.80	–1.34	–1.07
200	–.10	–1.12	–.61				1.50	.50	1.00	–.81	–.42	–.62
250	.46	–1.15	–.84	–.40	–1.56	–.98				.23	–.49	–.13
300	.09	–1.51	–.71	–.11	–1.03	–.57	.21	–.55	–.17			

When low tone is the constant tone, average is................ –.40
When high tone is the constant tone, averageis............... –.65
Average for the whole table is.............................. –.52

Conclusion:

When compared with a tone of constant intensity, SIMULTANEOUS tones varying from weak to strong (ASCENDING) are made .52 step weaker (or heard .52 step stronger) than SUCCESSIVE tones varying from weak to strong (ASCENDING).

TABLE IIIA

Ten intensities separate. All combinations taken together.

Obs.	Intensities 1	2	3	4	5	6	7	8	9	10
A	–.14	–.20	.10	[illegible]	0	.25	0	0	0	–.50
B	–.40	–.33	–.29	[illegible]	–.25	–.43	–.67	–1.17	–1.50	–1.67
Med.	–.40	–.26	–.11	9	–.25	–.29	–.25	–.50	–1.00	–1.33

The extent in steps to which the conclusion holds for the separate intensities is indicated in the last line.

SUCCESSIVE DESCENDING
COMPARED WITH
SIMULTANEOUS DESCENDING

The table values indicate the intensity steps that were (algebraically) added to the intensity of the Successive tone, to give the intensity of the Simultaneous tone.

TABLE IV

Ten intensities combined. 4800 Judgments.

Variable Tones

Constant	150			200			250			300		
	Obs.	Obs.		Obs.	Obs.		Obs.	Obs.		Obs.	Obs.	
Tone	A	B	Av.	A	B	Av.	A	B	Av.	A	B	Av.
150				–2.36	–.86	–1.61	–.66	–.73	–.70	–1.27	–1.28	–1.28
200	–.74	–.75	–.74				.85	1.05	.95	–.59	–.21	–.40
250	.50	–1.08	–.29	–.32	–1.32	–.82				.22	–.56	–.17
300	.32	–1.06	–.37	.02	–.50	–.24	.47	–.34	.06			

When low tone is the constant tone, average is................ –.70
When high tone is the constant tone, average is............... –.40
Average for the whole table is.............................. –.55

Conclusion:

When compared with a tone of constant intensity, SIMULTANEOUS tones varying from strong to weak (DESCENDING) are made .55 step weaker (or heard .55 step stronger) than SUCCESSIVE tones varying from strong to weak (DESCENDING).

TABLE IVA

Ten intensities separate. All combinations taken together.

Intensities

Obs.	1	2	3	4	5	6	7	8	9	10
A	–.10	–.22	.12	0	–.17	–.25	0	–.50	0	0
B	–.33	–.16	.09	–.29	–.33	–.37	–1.00	–1.00	–.75	–1.00
Med.	–.11	–.22	.09	–.22	–.33	–.37	–.50	–1.00	–.50	–1.00

The extent in steps to which the conclusion holds for the separate intensities is indicated in the last line.

ASCENDING
COMPARED WITH
DESCENDING

(Simultaneous and Successive series taken together)

The table values indicate the intensity steps that were added to the intensity of the Ascending tone, to give the intensity of the Descending tone.

TABLE V

Ten intensities combined. 9600 Judgments.

Variable Tones

Constant	150			200			250			300		
	Obs.	Obs.		Obs.	Obs.		Obs.	Obs.		Obs.	Obs.	
Tone	A	B	Av.	A	B	Av.	A	B	Av.	A	B	Av.
150				1.02	1.10	1.06	.84	.83	.84	1.02	.50	.76
200	.68	.85	.76				.96	1.27	1.12	.86	.87	.86
250	.86	.67	.76	.86	.99	.92				.83	.78	.80
300	.92	.71	.82	.88	.68	.78	1.01	.69	.85			

When low tone is the constant tone, average is................ .91
When high tone is the constant tone, average is............... .82
Average for the whole table is.............................. .86

Conclusion:

When compared with a tone of constant intensity, in mixed simultaneous and successive order, DESCENDING tones are made .86 step stronger (or heard .86 step weaker) than ASCENDING tones.

TABLE VA

Ten intensities separate. All combinations taken together.

	Intensities									
Obs.	1	2	3	4	5	6	7	8	9	10
A	1.00	1.10	.80	1.00	1.00	1.00	1.00	.75	.75	1.00
B	.80	.82	.87	.89	.84	1.00	1.00	.84	.75	.50
Med.	1.00	.90	.84	1.00	.84	1.00	1.00	.75	.75	.75

The extent in steps to which the conclusion holds for the separate intensities is indicated in the last line.

SUCCESSIVE
COMPARED WITH
SIMULTANEOUS

(Ascending and Descending series taken together)

The table values indicate the intensity steps that were (algebraically) added to the intensity of the Successive tone, to give the intensity of the Simultaneous tone.

TABLE VI

Ten intensities combined. 9600 Judgments.

	Variable Tones											
	150			200			250			300		
Constant	Obs.	Obs.		Obs.	Obs.		Obs.	Obs.		Obs.	Obs.	
Tone	A	B	Av.	A	B	Av.	A	B	Av.	A	B	Av.
150				-1.70	-.20	-.45	-.71	-.46	-.58	-.85	-1.17	-1.01
200	-.31	-.98	-.64				1.84	.96	1.40	-.55	-.64	-.60
250	.62	-1.12	-.25	-.37	-1.46	-.92				.15	-.56	-.20
300	.27	-1.50	-.62	.06	-.73	-.34	.49	-.31	.09			

When low tone is the constant tone, average is............... -.24
When high tone is the constant tone, average is.............. -.45
Average for the whole table is............................... -.34

Conclusion:

When compared with a tone of constant intensity, in mixed ascending and descending order, SIMULTANEOUS tones are made .34 step weaker (or heard .34 step stronger) than SUCCESSIVE tones.

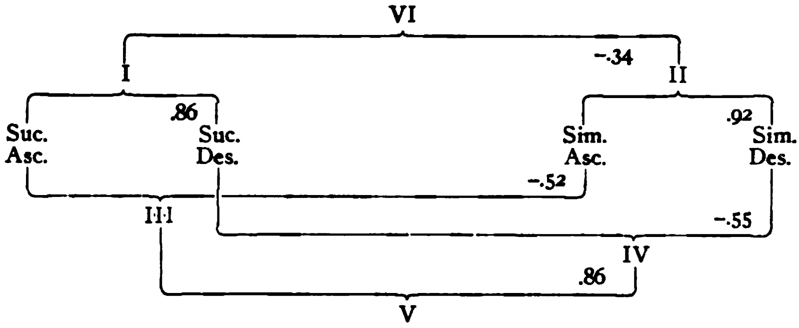
TABLE VIA

Ten intensities separate. All combinations taken together.

	Intensities									
Obs.	1	2	3	4	5	6	7	8	9	10
A	-.08	-.10	0	00	-.22	0	.25	.29	0	-.25
B	-.50	-.26	-.14	-.28	-.24	-.50	-.50	-1.25	-.75	-1.50
Med.	-.10	-.26	0	-.28	-.24	-.50	-.50	-.57	-.25	-.84

The extent in steps to which the conclusion for the separate intensities holds, is indicated in the last line.

5. Comparison and Discussion of Results



The above diagram will show more clearly how the tables and conclusions are related. It is to be remembered that the original data was in the form of four series. These four series form the starting points of the braces which connect those series which were used to make up the tables indicated by the Roman numerals. The numbers in the right arm of each brace are the extent in steps which the series nearest the number was made stronger (or heard weaker) if the value is positive, or made weaker (or heard stronger) if the value is negative, than the companion series. Thus, the —.52 in the right arm of the brace III means that the simultaneous-ascending tones were made .52 step weaker (or heard .52 step stronger) than the successive-ascending tones, when compared with a tone of constant intensity. The same principle is carried through for the other combinations.

From the diagram it also appears that the simultaneous tones were made weaker (or heard stronger) than the successive tones, and the descending tones are made stronger (or heard weaker) than the ascending tones.

It will be well to make clear just what this means. Consider as an illustration the comparison between simultaneous and successive tones of which the tone 200 is the constant and the tone 250 the variable. Assume that 200 is set at intensity 5 or at 36 mm. The tone 250 is started at silence by the observer and slowly made stronger while being *successively* compared with the intensity of 200. Suppose when they are equal that the scale of 250 also reads 36 mm. This reading is recorded. Now 250 is again returned to silence and then gradually made stronger, but this time the adjustment is made while the tones are sounding *simultaneously*. In this case it is found that 250 is not made as strong as when the comparison was made successively. In other words, when given simultaneously 250 was reported equal *before* it actually reached the position at which it was stopped when it was compared successively. Briefly, 250 was left weaker when given simultaneously than when given successively.

Introducing a subjective term, we can say that 250 was "heard" as equal while objectively it was still weaker than it had been when reported equal successively. Advancing another step, when a tone is *made weaker* under a set of conditions (A) than it is under a set of conditions (B), when the instructions actually are to make the tones "equal" in intensity, we may say that the tone was "heard stronger" under the (A) conditions. This means that had the resonator actually been advanced to the position which it had in the (B) set, it would have been *judged stronger* than the constant tone.

From the foregoing it should be clear that the subjective characterization "heard" is derived from the *reaction*. This is the reason that it has been treated parenthetically in the tables and in the discussion. It is the reactions—the moving of the resonators more or less—which form the basis of this experiment. The subjective terms "heard stronger or weaker" are introduced for two reasons: 1. Many psychologists are interested in the subjective conditions; 2. The opposition between the relations "making stronger" and "hearing weaker" is likely to be overlooked. It is easy to conclude that because a tone was "made stronger" it is also "heard stronger" whereas a little reflection will show that the opposite is the case.

The type of the reactions which the observers made in the experiment with ascending and descending tones can be described by saying that the reactions did not go far enough. In tones varying from weak to strong, the observer left the tones too weak; in tones varying from strong to weak, they were left too strong. It is possible that the stimulus for stopping the reaction is not only the intensity of the tone but also the amount of *change* in intensity which it has undergone. When the observer had changed the tone a certain amount, he gave the "equal" reaction, though with respect to intensity the reaction was premature. It must be remembered, however, that the amount of change in the intensities of the tones varied for the different steps. Thus the ascending tones were always started at silence. When working on intensity 1, the change between silence and intensity 1 is very little as compared with the change from silence to intensity 10. For the intermediate steps, of course, there were intermediate degrees of change.

Another fact which tends to reduce the effectiveness of the *amount of change* as a substitute for the reaction to the intensity only, was the fact that the ascending and descending series alternated. The amount of change in intensity when ascending is just the opposite of what it is in descending. It is only in the medium intensities that the amount of change is the same both for ascending and descending tones. This does not mean that the change in intensity is without effect, only it is not likely that it may be substituted for the reaction to the intensity. It seems to the writer that it is more correct to say that the judgment "equal" in ascending and descending tones is the result of both the (1) actual intensity of the tones and (2) the amount of change in intensity which the variable tone has undergone. These two factors interact in such a way that ascending tones are made weaker than descending tones.

The type of reaction characteristic of the judgment that was made when successive and simultaneous tones are compared, is of a different order than that of ascending and descending tones. When the intensity of successive-ascending tones is compared with that of simultaneous-ascending tones (Table III) the direction and magnitude of the change in intensity is the same for both series, in that they both start from silence and are brought to equality. We find, however, that the simultaneous tone is made about a half step weaker than the successive tone. This reaction seems to be conditioned only by the tone intensity.

Whether the stimulus which releases the "equal" reaction prematurely (in the physical sense) is simply the tone intensity cannot be determined without further experimental analysis of the tone intensity reaction. Previous habits of tone perception most probably play a role. Do we have the habit of giving attention to the variable rather than to the constant tone? Do we give attention to the higher rather than to the lower tone? Do we give attention to the components of a compound tone differently when the difference of the vibration rates between them is great than when it is small? Do we attend differently to the intensity when the interval is consonant than when it is dissonant?

A scientific analysis of the tone intensity judgment or tone intensity reaction will make it necessary that these questions be answered not only affirmatively or negatively but quantitatively. As we approach the solution of some of these questions we can subject the various theories of audition to a much more searching and effective criticism than it is possible from mixed qualitative and a priori considerations.

Quite early in the experiment it was noted that there was a considerable difference between the averages of the observations in which the low tone was the constant tone and those in which the high tone was kept at constant intensity. This is so apparent in all of the tables that it seems improbable that it was due to some error in the control. In comparing the tones successively, each resonator was alternately opened and closed as often as was necessary to enable the observer to shift the variable resonator until the variable tone seemed equal in intensity to the constant tone. During this time each tone may have been sounded a dozen times and whether the high tone had been sounded first or the low tone first, would have been forgotten. Furthermore, no definite plan was followed as to which tone, variable or constant, higher or lower, was the starting tone. In the simultaneous tones both resonators were opened at the same time and left open until a judgment had been made.

From this it does not appear that the difference between the averages when the higher tone is constant or the lower tone constant, is due to any constant in the manner of presenting the tones. There is involved in this fact perhaps some habit of auditory perception. So far as the sense organs in the ear or the character of the sound waves are concerned there should be no such difference in the averages. One thing which bears on this subject is the difference between the relative intensities of successive and simultaneous tones as revealed by tables III, IV, VI, in which it was found that the simultaneous variable tones are made weaker than the successive variable tones. This shows that when tones sound simultaneously they affect each other in a manner differently than when they sound successively. The question arises, do we approach the simultaneous tone conditions as the intervals between successive tones become shorter and shorter, or even as combinations which start as successive tones are left to overlap and become partly simultaneous? The observers noted frequently that the intensity judgments for successive tones were different from the intensity judgments of simultaneous tones. To illustrate, if the intensity of tone 150 is constant and 200 is made of the same intensity successively, then when both sound simultaneously 200 will be found to be too strong. It may be adjusted again to 150 and the judgment that 150 and 200 now sounding simultaneously are equally strong will be clear and unambiguous, but to say that the intensities of the simultaneous tones are the same as the intensities of the successive tones is quite a different matter.

To answer this question it is necessary that a third or standard tone be introduced according to the following plan. Take tones 150A and 150B and 200; equate 150A with 150B for intensity, successively; then adjust 200 until it is equal in intensity to 150B, successively; then treat 150B and 200 as a single tone and sound simultaneously, varying 150B until it is equal to 200. The difference between the readings of 150A and 150B will show the influence of the tone 200 on the intensity of 150B when given simultaneously.

It is in some such manner that the influence of one tone upon another, so far as the intensities are concerned, will need to be worked out, before it will be possible to explain why the averages of the tables seem to be influenced so much by whether the high or the low tone is the constant tone. This is the next problem that the writer hopes to take up, but preliminary to this is the development of some simple absolute standard for tone intensity.

The individual differences between Obs. A and Obs. B have not been treated in this paper. All the tables will reveal the fact that they are of considerable magnitude but to try to explain these differences with the data of only two observers might lead to conclusions which would need to be materially modified with a greater number of observers. It would have been better, of course, to have started with a greater number of observers but for reasons indicated in another part of this paper it was not found practicable. Besides the results of this experiment will make it possible to attack the problem of individual differences in a much simpler way.

The smaller (A) tables which give the values for the ten intensities separately, show that the phenomena which are characteristic for each table are rather evenly distributed over the ten tone intensities.

The strengthening of the descending tone as shown by table IA occurs mainly with the medium intensities. The same thing is to be noted in IIA.

The weakening of the simultaneous tone as shown by table IIIA is least in the medium intensities, but in table IVA it is least with the lower intensities. It seems to be clear, however, that the weakening of the simultaneous tones is greatest at the higher intensities. This is perhaps only an extension of the same principle. If simultaneous tones are weakened, we should expect them to be weakened most where the intensity is greatest, because greater differences in intensity are possible where the tones are loud than where they are weak.

6. THE VARIABILITY OF INTENSITY JUDGMENTS

Tables VII to XI show the extent to which the judgments of intensity varied. The values of the tables are in intensity steps and represent the range over which half of the judgments were distributed. Thus the value 1.80 taken at random from the combination 150-200, table VII, means in this case that one half of the intensities were found within less than 2 intensity steps. This value may also be considered as a measure of the accuracy of the judgments in that one-half the value indicates the deviation of these judgments above and below a given intensity. The way in which the variability value is derived is as follows.

To consider the variability for the combination successive-ascending and simultaneous-ascending for the intensity 1 (81 mm.) the values of which are given in the specimen table, page 39, and arranged in order of magnitude on page 40. In this series there are 20 judgments, the median value of which is 88. By taking the value in the fifth place 84 and the value in the sixteenth place 95, these limits will include slightly more than one-half of the judgments. The difference between these limits is 95 — 84 = 11 mm. which represents the limits within which the resonator moved for one-half the cases. In reducing the millimeters to intensities, the difference 11 is multiplied by the reciprocal .10 (page 41) which is the factor in the region of the scale 88 mm. This gives the value 1.10 which is the measure of variability.

Variability of Successive Tones
(Ascending and Descending taken together.)

Table VII

Ten intensities combined. 4800 Judgments.

Variable Tones

	150			200			250			300		
Constant	Obs.	Obs.		Obs.	Obs.		Obs.	Obs.		Obs.	Obs.	
Tone	A	B	Av.	A	B	Av.	A	B	Av.	A	B	Av.
150				1.94	1.65	1.80	1.52	1.76	1.64	1.78	1.31	1.54
200	1.45	1.20	1.32				1.70	1.65	1.68	1.40	1.47	1.44
250	1.35	1.10	1.28	1.46	1.34	1.40				1.62	1.32	1.47
300	1.33	1.24	1.38	1.06	1.25	1.16	1.57	1.16	1.36			

When low tone is the constant tone, average is................ 1.60
When high tone is the constant tone, average is............... 1.32
Average for the whole table is............................... 1.46

Variability of Simultaneous Tones
(Ascending and Descending taken together.)

Table VIII

Ten intensities combined. 4800 Judgments.

Variable Tones

	150			200			250			300		
Constant	Obs.	Obs.		Obs.	Obs.		Obs.	Obs.		Obs.	Obs.	
Tone	A	B	Av.	A	B	Av.	A	B	Av.	A	B	Av.
150				1.42	1.96	1.70	1.49	1.79	1.64	1.64	1.35	1.50
200	1.15	1.28	1.22				1.88	2.19	2.04	1.75	1.71	1.73
250	1.27	1.35	1.31	1.35	1.46	1.40				2.08	1.36	1.72
300	1.77	1.45	1.61	1.48	1.52	1.50	1.65	1.31	1.48			

When the low tone is the constant tone, the average is........ 1.72
When high tone is the constant tone, average is............ 1.42
Average of the whole table is.............................. 1.57

VARIABILITY OF ASCENDING TONES

(SUCCESSIVE AND SIMULTANEOUS TAKEN TOGETHER.)

TABLE IX

Ten intensities combined. 4800 Judgments.

Variable Tones

Constant	150			200			250			300		
Tone	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.
150				1.70	1.47	1.58	1.44	1.96	1.70	1.54	1.64	1.59
200	1.42	1.29	1.36				2.38	1.67	2.02	1.57	1.52	1.54
250	.98	1.47	1.22	1.21	1.80	1.50				1.44	1.42	1.43
300	1.10	1.54	1.32	1.02	1.31	1.16	1.44	1.19	1.32			

When low tone is the constant tone, average is............... 1.64
When high tone is the constant tone, average is............... 1.31
Average for the whole table is............................. 1.48

VARIABILITY OF DESCENDING TONES

(SUCCESSIVE AND SIMULTANEOUS TAKEN TOGETHER.)

TABLE X

Ten intensities combined. 4800 Judgments.

Variable Tones

Constant	150			200			250			300		
Tone	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.	Obs. A	Obs. B	Av.
150				2.44	1.45	1.94	1.58	2.04	1.81	1.96	1.76	1.86
200	1.15	1.53	1.34				2.66	1.99	2.32	1.50	1.69	1.60
250	1.24	1.17	1.20	1.40	1.68	1.54				1.50	1.32	1.41
300	1.34	1.29	1.32	.98	1.18	1.08	1.54	1.40	1.47			

When low tone is the constant tone, average is............... 1.82
When high tone is the constant tone, average is............. 1.32
Average for the whole table is............................. 1.57

VARIABILITY WITH RESPECT TO INTENSITIES

(SUCCESSIVE, SIMULTANEOUS, ASCENDING AND DESCENDING COMBINED)

TABLE XI

Ten intensities separate. 9600 Judgments. All combinations.

Intensities

Obs.	1	2	3	4	5	6	7	8	9	10
A	1.50	1.33	1.33	1.61	1.37	1.43	1.50	1.50	1.50	1.25
B	1.40	1.37	1.50	1.44	1.50	1.25	1.33	1.50	1.67	1.50
Med.	1.50	1.36	1.40	1.44	1.37	1.33	1.43	1.50	1.50	1.50

Average for the whole table is........................... 1.48

The tables show that successive tone intensities are less variable than simultaneous tone intensities, and ascending tone intensities less variable than descending tone intensities. Introspectively it seemed to the observers that the simultaneous judgments were the more accurate though the tables show the reverse. In the descending judgments the introspection agrees with the tables. However, the differences in the variability are not pronounced. It is rather remarkable that the judgments are so constant. This is a promising fact for future work on sound intensity. The average of *all* the tables is 1.48 steps. Half this value .74 represents the deviation of half the judgments, above and below a hypothetical average intensity.

For example, if the constant tone is set at intensity 5 then one-half of the judgments in making a variable tone of equal intensity will be found to lie between the intensities 4.26 and 5.74. This value 1.48 also corresponds well with what was expected in planning the experiment, namely, that the difference between the intensity steps should be supra-liminal. Had they been subliminal, the value would have been greater than 2.00. Since we started with ten intensity steps and the deviation is plus and minus .74 we can say within the limits of the intensities actually used, there are 14 just noticeable differences in intensity.

By extending the intensities to very loud and very faint it seems conservative to suppose that at least 25 tone intensities could be discriminated.

The differences between the averages when the high tone is the constant tone and the low tone is the constant, are perhaps even more pronounced than for tables I to VI. When the high tone is the constant tone, the variability is considerably less. This is of importance for future experiments in tones as it tends to show that where the nature of the investigation permits it, comparisons should be made with the higher tone as the constant or standard tone, rather than the lower.

The variability for the separate intensities as shown by table XI is slightly less for the medium intensities. However, even the variability of the limits, 1.50 or plus or minus .75 show that the intensities are still considerably above the limen. The table also shows that the value .6 which was used as the base for the logarithmic series was well chosen.

According to this the limen for tone intensities should be found at squares of the multiples of .5 or less, when distance in millimeters of the mouth of the resonator from the prongs of a tuning fork is taken as a measure of the intensity.

7. RELATION BETWEEN VARIABILITY AND DIFFERENCE IN VIBRATION RATE

In table XII it is shown that the accuracy with which intensity judgments are made is not proportional to the difference in vibration rates. The intensities of two tones near each other in vibration rate are not necessarily judged more accurately than the intensities of two tones farther apart. The factors which are involved in making a judgment of intensity have not been isolated in these experiments and until they have been, intensity judgments will be of a mixed character in which both the tonality and vocality of the tones are involved.

It is because he is convinced of the complex character of the intensity judgment, that the writer has refrained from treating the individual differences between the two observers of this experiment until he has made experiments directed toward a further analysis of the tone intensity reaction.

At the beginning of the experiment it was supposed that the variability of the intensity judgments would be least when the difference between the vibration rates of the tones was least, but within the limits of the vibration differences within which this experimental work lies, it was found that the judgments were more accurate when the difference in vibration rates was 100. The following table gives the variability for the three vibration differences which were used.

TABLE XII

	Difference in Vibration Rates.		
	50	100	150
Variability	1.58	1.44	1.50

This shows that the variability was greatest when the difference in vibration rates was only 50, whereas at a difference in vibration of 100, the variability was least. Even at 150 the variability is not as great as at 50 but since there are only two combinations out of the twelve in which the difference was 150, reliable conclusions cannot be drawn. The significant thing is that the variability is so constant. The combinations of this investigation do not exceed an octave and it would be interesting to know whether the variability shows a correlation with octave relationships or not.

8. RELATION BETWEEN VARIABILITY AND CONSONANCE

The preceding table leads to the idea that perhaps the variability is correlated with the dissonance or consonance of the intervals which were used. Table XIII shows the variability with respect to the intervals.

TABLE XIII

Ratio	1:2	2:3	3:4	3:5	4:5	5:6
Name	Octave	Fifth	Fourth	Maj. VI	Maj. III	Min. III
Var.	1.56	1.60	1.53	1.47	1.73	1.46

From this table it cannot be concluded that the consonance of the interval is correlated with the variability. However, the data of this experiment gave only two combinations of forks for each interval, and the effect would need to be strong indeed had it appeared. From the impression which gradually developed during the course of the experiment it seems probable to the writer that both difference in vibration rates and the ratios of the intervals have an influence upon the judgments of the tone intensities. It is these facts mainly which led him to conclude that the intensity judgment in audition is really a mixed judgment. A tone may be judged as strong as another tone one moment, but presented again a few moments later, they will be judged of different intensity.

A complete analysis of the tone intensity reaction will need much more experimental data than is contained in these pages. But the outlook is promising for one who is able to meet the mechanical difficulties incident to the control of conditions.

9. NOTES ON DRAWINGS AND PHOTOGRAPHS

Small circles about 1-16 inch diameter, represent binding posts or terminals. In drawing C fig. 3, they represent the kind of terminal shown in detail in D fig. 3.

The next sized circle, ⅛ inch diameter represent sliding contacts as in rheostats or starting boxes.

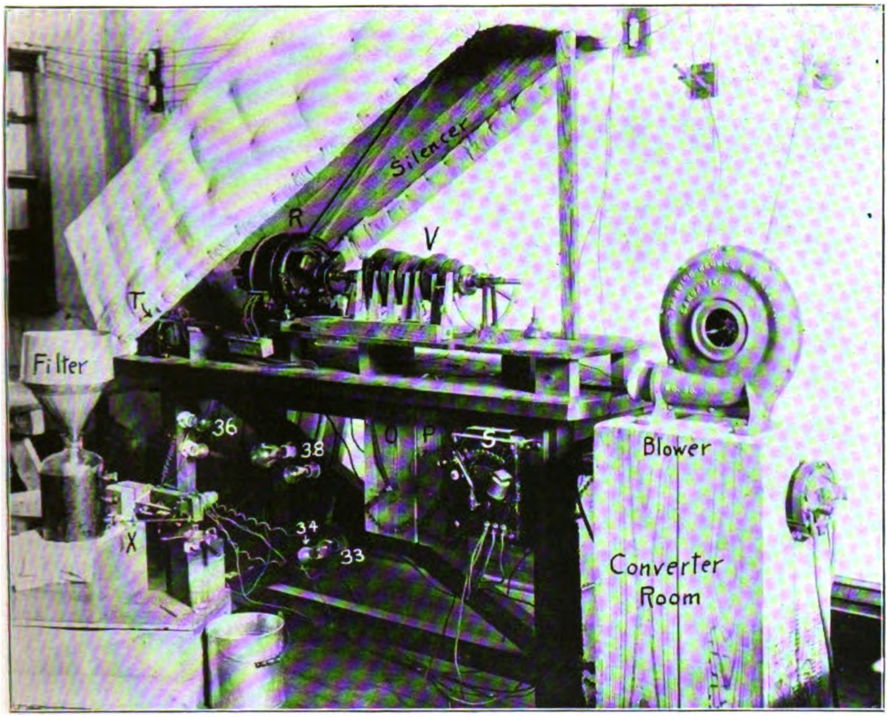
Double circles, the outer one of which is ⅛ inch diam. represent regular 110 volt lamp sockets. When an F is placed near the circles, this means that the socket is used as a fuse and carries a plug of about 5 amperes, 110 volts, capacity.

All terminals having the same numbers are connected to the same wires.

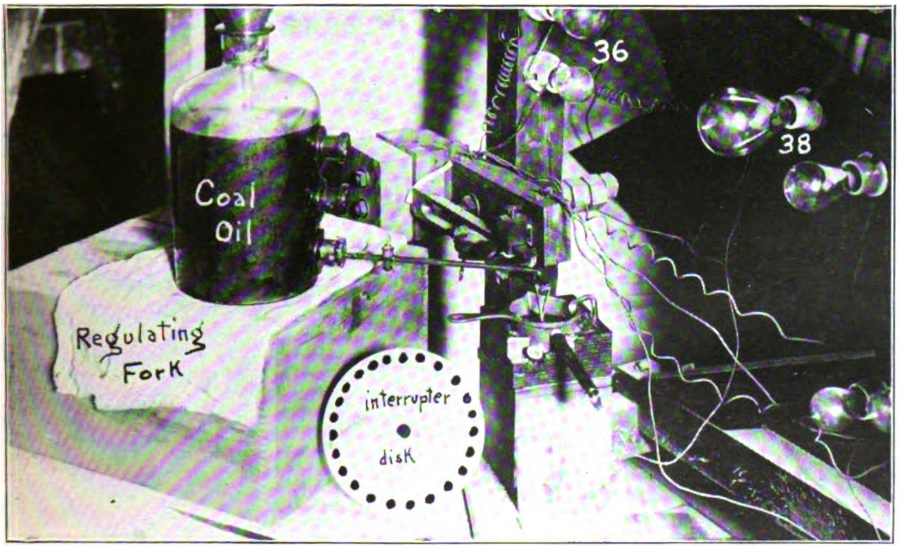
The numbers or letters on the photographs refer to similar numbers on the drawings or in the description.

The room in which the converter and regulating fork are located is separated from the experimental room by a large hall. They are not connected in any way except by the electrical wiring.

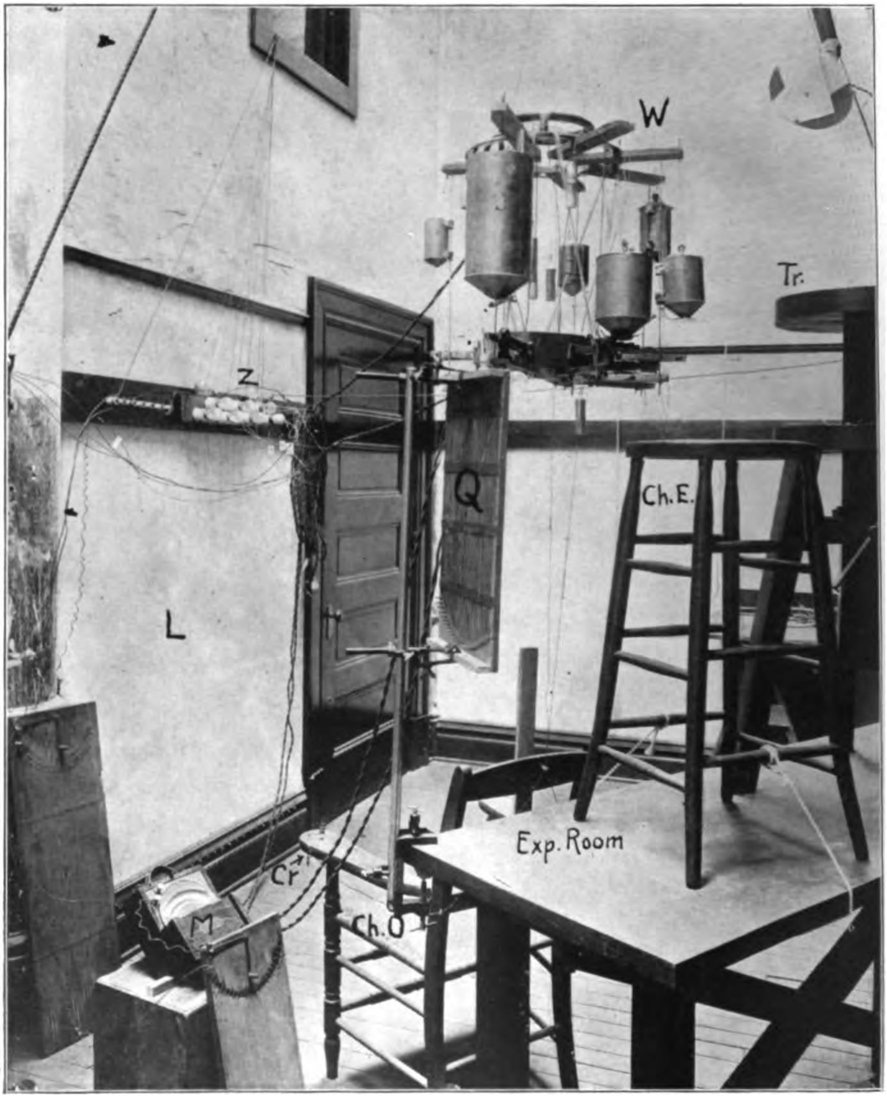
These two rooms might have been separated by a still greater distance and it would then not have been necessary to construct the silencing hood for the converter shown in the photograph. This hood drops down and encloses the converter when it is running, thus reducing the noise so that it cannot be heard in the experimental room when the two doors which seperate the rooms are closed. When the hood is down, the blower also shown in the photograph blows air into the silencing hood and against the converter to keep the latter from heating.



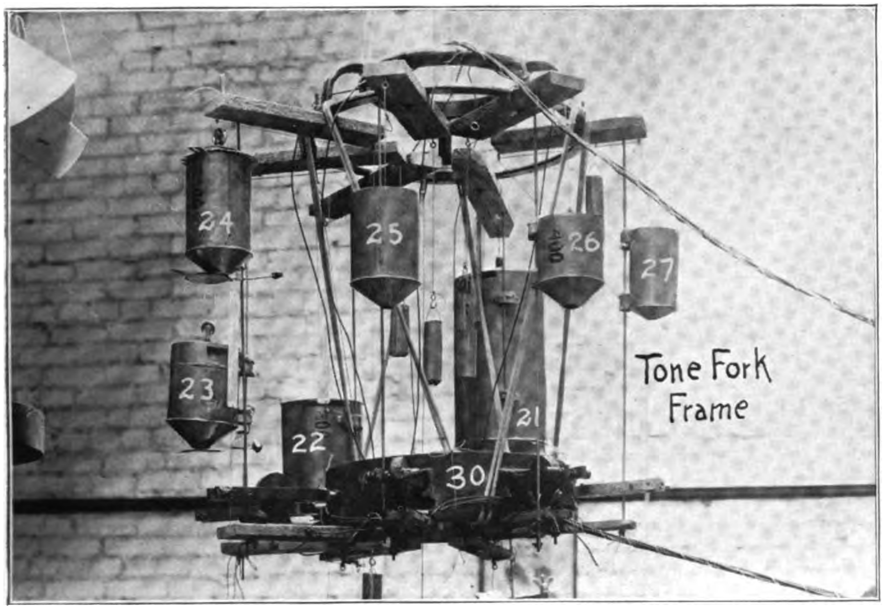
Photograph of Converter Room and apparatus for driving tone forks



Enlarged view of Regulating Fork.



PHOTOGRAPH OF EXPERIMENTAL ROOM IN WHICH THE TONES ARE PRODUCED.



Enlarged View of Tone Fork Frame showing resonators and tuning forks.

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The Qualitative Relation Between Complementary and Contrast Colors

By

HELEN D. COOK AND FLORENCE M. KUNKEL

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THE QUALITATIVE RELATION BETWEEN COMPLEMENTARY AND CONTRAST COLORS

§ 1. Historical summary and statement of problem.

For many years it has been recognized that the qualitative relations between colors, in their "pairing off" as complementaries, contrast colors, and after-images, are much more complex than they were supposed to be at the time of the original formulation of the historical color-theories. The essence of the Hering theory seems to demand that the same colors which pair off as complementaries shall also contrast with each other, both simultaneously and in negative after-images. Yet, after Goethe, it was left primarily to the followers of the Hering school itself to point out the discrepancies between the pairs of complementary and those of contrasting colors. A brief summary of the results reached by previous investigators will furnish the best possible introduction to this report of the Wellesley experiments.

As early as 1810, Goethe[1] noted the most marked of these discrepancies. Blue and yellow, when mixed in the right proportions, give a single sensation of colorless light. But the after-image of the same blue—when produced under the ordinary conditions of a relatively long fixation of a colored surface of medium intensity—is not yellow, but orange. Similarly, the after-image of yellow is not blue, but violet. In other words, the after-images both of blue and of yellow are redder than the corresponding complementaries. Johannes Müller[2] notes the same anomaly in the case of simultaneous contrast colors, as observed in colored shadows.

During the early days of the Hering-Helmholtz controversy the chief question seems to have been the relation between the complementary and the so-called "elementary" or "opposite" colors. According to Hering's physiological theory, the "Urfarben," or introspectively "elementary" and "opposite" colors, red-green, and blue-yellow, should pair off in exactly the same way in the three cases of complementary colors, of negative after-images, and of colors induced by simultaneous contrast. As everyone knows, a long and hot discussion raged between the Hering and the Helmholtz schools about Urgrün and Urrot, which, if "elementary," refuse to be complementary, and if complementary, can, in the present writer's opinion, be called "elementary" only by a vigorous stretching of the introspective imagination. This intractability of Urgrün and Urroth had a two-fold influence on scientific discussion: first, it served to distract the attention of experimenters from the equally interesting if less spectacular behavior of Urgelb and Urblau under certain conditions; and second, it thereby led investigators to place the emphasis on the differences between "opposite" or "elementary" colors on the one hand, and on the other either complementary or contrast colors, rather than on the differences between the two last-named themselves. Hering[3] however, noted that under ordinary conditions of daylight adaptation the negative after-image is not exactly the complementary color, but seems to assume that complementary and "opposite" colors are the same. Later[4] he drops the complementary color from the comparison when he says that the discrepancy between after-image and opposite color disappears under conditions of dark adaptation.

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[1] *Zur Farbenlehre,* Cotta, Tübingen, 1810, pp. 58 ff.

[2] *Handbuch d. Physiol.,* 2, p. 373, 1837.

It remained, however, for Tschermak[5] to make a more detailed study of the various color relations involved. Tschermak's work, since in a sense it forms the basis for the present study, must be outlined in some detail. As his title indicates, his investigation is concerned with the relations between "Gegenfarben," or "opposite" colors, complementary colors, and contrast colors, though, like Hering, he is interested rather in the way in which both complementary and contrast colors differ from "opposite" colors, than in the way in which the first two differ from each other. All his experiments were performed with rotating disks of Rothe colored papers as seen through two apertures in a gray screen in diffuse daylight. In most of the tests the subject fixated a point midway between the two apertures, so that the majority of the experiments deal with slightly extra-foveal vision. The results were the same, however, in the tests made with direct fixation. The "opposite" colors could be determined only for the two pairs of "elementaries," red-green, and blue-yellow. For each pair the two colored disks were varied until the subject declared them to be introspectively "elementary" and opposite in quality. Complementary colors were found by the usual method of matching a color mixture to gray, the color mixture on one disk, the gray on the other. Contrast color for Tschermak usually means the color of the negative after-image, which was determined by projecting the after-image on the gray screen and matching to it a color mixture on one of the rotating disks. His results were:

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[3] *Zur Lehre vom Lichtsinne*, §§ 44, 45, 46, 1874.

[4] Pflüger's Arch. f. d. ges. Physiol. 43, footnote p. 2, 1888.

[5] *Tschermak, A. von, Über das Verhältnis von Gegenfarbe, Kompensationsfarbe, und Kontrastfarbe*, Pflüger's Arch. f. d. ges. Physiol. 117, 473-497, 1907.

1. That the subjectively opposite colors are not exactly complementary: "elementary" blue and yellow are made complementary only by the addition of a small amount of red; "elementary" red and green by the addition of a considerable amount of blue.

2. That the discrepancy between contrast colors and opposite colors is in the same direction and still greater in amount; *e.g.* (in agreement with Goethe) the after-image of blue is orange (= yellow + red), of green is purple (= red + blue) etc. In general, that is, the complementary color, and still more the contrast color, differs from the true opposite color by the "subjective addition of a certain amount of red and of blue."[6]

Following Hering, Tschermak explains the differences noted as due to the unequal adaptation of the eye to the different colors, under conditions of ordinary daylight adaptation. He supposes that the daylight adapted eye is in reality adapted to purple (red-blue), and therefore that the complementary and contrast colors take on a purplish caste as compared with the true opposites. Just how or why this purplish adaptation takes place in ordinary daylight is not quite clear. Tschermak explains it as due (1) to the (physical?) color of the daylight itself; (2) to the selective absorption of the diasclerotic light by the pigment of the lens, retinal epithelium, macula, and possibly visual purple. Whether these conditions can really cause an appreciable purplish adaptation of the eye must be left to the decision of the physicists and physiologists.

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[6] *op. cit.*, p. 487.

A second criticism or question which suggests itself to the writers is in regard to the physiological process by which (according to the Hering or any other color theory) adaptation *to* any color could have just the effect ascribed to it *during* adaptation. Tschermak quotes as substantiating his theory previous work of Hess,[7] in which the latter shows that fatigue for or partial adaptation to a given color makes any other color, seen immediately afterward, tend to take on a tinge of the complementary of the original color. Tschermak therefore argues that adaptation to a given color would have just the opposite effect on the after-image of another color, *i.e.*, would tend to make it take on a tinge of the adaptation color. For example, Hess shows that fatigue for (or partial adaptation to) red makes a blue seen immediately afterward look greenish. The after-image of that greenish-blue might then conceivably look more reddish than the after-image of the same blue under conditions of neutral adaptation. But even if this be the case, it does not necessarily account for the reddish tone of the after-image of blue in the experiments of Tschermak and others. For Hess was experimenting with colors as seen *after* fatigue for a given color, Tschermak with vision *during* adaptation to ordinary daylight, which he supposes to be really adaptation to purplish light. And how far the two conditions are comparable seems to the writers to be extremely questionable. Moreover, whatever effect adaptation may have on the quality of the after-image, unless the illumination is very appreciably altered, it should not influence the quality of the complementary color, as determined by color equations. For, unless psychologists have been mistaken about the laws of color mixture, adding the adaptation color (or its complementary) to both of the mixtures forming the equation should not alter the validity of the equation.[8]

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[7] *Über die Tonänderung der Spektralfarben durch Ermüdung mit homogenem Licht,* Arch. f. Ophth. 36, 1-32, 1890.

Tschermak tests his hypothesis, however, by experiments with artificial adaptation, in which he finds a reversal of the anomaly under conditions of adaptation to yellowish-green. It is to be regretted that these experiments either are so few or are so inadequately reported. The actual results given in the tables show only two tests:[9]

1. On March 27 the subject was adapted to yellowish-green by wearing glasses of that color for half an hour before and during the experiment. "Urblau" was determined, also its complementary, which was found to be "schwach grünlich gelb."

2. On April 30, with the same yellowish-green adaptation, "Urblau" was found, and its negative after-image, which was "grünlich gelb."

These two tests with a single subject seem rather scanty justification for Tschermak's conclusion that "die Kompensationsfarbe (complementary color) weicht von der Gegenfarbe durch Addition eines bestimmten Betrages der Adaptionsfarbe ab. Weit beträchtlicher ist die Addition von gleichfarbiger Erregung im Nachbildprocesse, in der Kontrastfarbe."[10] And not only are these tests insufficient in extent, but the numerical data given lead one to question Tschermak's interpretation of them. One suspects that the subject's adaptation to his yellowish-green glasses was not complete, since the chief difference between the results with and those without artificial adaptation lies in the determination of "Urblau." With normal adaptation the subject judged as introspectively "Urblau" a color made up of blue and green papers in the proportion of 4.2:1 (average of 5 determinations).[11] With yellowish-green adaptation the corresponding proportion is 10:1 (average of 2 determinations). In other words, the blue which looked "elementary" to him under normal conditions, looked a greenish blue through the yellowish-green glasses, even after he had worn the latter for half an hour. And the blue which he calls truly "elementary" under these conditions looked purplish to him under normal adaptation conditions. Small wonder, then, that the complementary and contrast colors of the second blue are a more greenish yellow than those of the first. For this greenish caste of both the complementary and the contrast yellow is obviously due, not to the artificial adaptation of the eye to the yellowish-green light, but to the more purplish quality of the Urblau determined under these conditions.

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[8] *Cf.* the "third law of color mixture." Titchener, E. B., *Students' Manual Qualitative*, p. 5, 1901.

[9] Tschermak, *op. cit.*, Table III in Appendix.

[10] *Op. cit.*, p. 490.

[11] *Op. cit.*, table 1.

The judgment seems inevitable, therefore, that Tschermak's actual results, while they established the fact that under normal conditions both complementary and contrast colors tend to be more purplish than the true "opposite" colors, nevertheless do not justify his theoretical conclusion that these discrepancies are due to the purplish adaptation of the eye in ordinary daylight. A further testing of this conclusion was one of the objects of the Wellesley experiments.

The main purpose of these experiments, however, was the study of that phase of the subject which had been touched only incidentally by other investigators, namely the qualitative relation between complementary and contrast colors. Tschermak, following Hering, laid the emphasis on the differences between opposite colors and complementaries, and referred only incidentally to the quality of the contrast color, contenting himself with the statement that, when the complementary colors vary from the true "opposites," the contrast colors vary "in the same direction" or "still more." His numerical data, however, often show appreciable differences between contrast and complementary colors, and thus agree with the experimental observations in the Wellesley laboratory which originally led the writers to take up this problem. These observations were made during several years' experience in routine color experiments, and seemed to show that the difference in quality between those colors which are complementary to each other, and those which induce each other by contrast, either simultaneous or successive, is much greater than is usually realized. This is especially true in the case of blue and yellow. The most accurate student-observers in the laboratory found consistently (in agreement with Goethe and Johannes Müller) that the contrast color of yellow is violet, not blue, and that the contrast color of blue is a very reddish orange instead of yellow. The two main problems of these experiments may, then, be stated as follows:

First: To determine the qualitative relation between complementary and contrasting colors.

Second: To determine the dependence of this relation on the conditions of adaptation.

A third problem might be stated as a by-product of the first, namely, the dependence of this relation on the brightness difference between contrast-inducing and contrast-suffering surfaces. The results bearing on the last point, however, though they will be reported in the text below, are not complete enough to be of more than incidental interest.

§ 2. General Method of Experiments.

The main problem, as stated above, is the relative quality of those pairs of colors which are complementary to each other, and those which induce each other by contrast, either simultaneous or successive. The exact quality of the negative after-image is very hard to determine, so that in most of our experiments we confined our attention to the simultaneous contrast color. The method, then, consists essentially in determining as accurately as possible the quality of the complementary, the simultaneous contrast, and, in a few cases, the negative after-image of a given color, and in comparing with each other the results thus obtained. All experiments were made with reflected lights—revolving disks of Hering colored papers seen in diffuse (north-west) daylight. It seems unnecessary to describe in detail the methods used for determining complementary and contrast colors, since these took the orthodox form of making color-equations.[12] In most of the tests the matches were made, as by Tschermak, with slightly excentric fixation. The two disks to be matched ("large" size,

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[12] *Cf.*, Titchener's Experimental Psychology, *Students' Manual Qualitative*, pp. 6-7, and 17.

9.6 cm. radius; "small" size, 5.5 cm. radius) were set up on two rotating pivots 32 cm. apart, with a fixation point midway between them. The subject sat at a distance of 2 meters. The angle of eccentricity was therefore 4°35′. Complementary colors were found by matching a color mixture on one disk to a black-white mixture on the other, both disks large size. In the determination of the contrast color a small disk of black, white, and the necessary colors was matched to the color taken on by a black-white contrast ring on a large colored disk. The contrast rings were 1.8 cm. wide, inside radius 4.7 cm. The brightness of the contrast ring was equal to that of the colored background, as determined by the flicker method,[13] in all tests except those of groups I and II, which were especially designed to test the effect of variations of brightness on the quality of the contrast color.

The subjects serving in the experiments were seven in all: three trained in general experimental work, C. and K., the writers of this report, on whom the large body of the experiments was made, and F., a Wellesley College Senior, who was at the time taking her third course in experimental psychology; and the four untrained subjects, D., H., Ke., and M., undergraduates in a first course in experimental psychology.[14] None of the subjects was especially practiced in color observations. K. was experimenter in all tests except those made on herself, and a few on the observer F. These tests were conducted by C. These two main subjects, C. and K., knew of necessity the purpose and method of the experiments. They took, however, every possible precaution to keep themselves uninfluenced by expectation, including that of examining no results of any subject until the entire series of tests was complete. The subject F. knew of the purpose and plan of the work only in the most general way, and the four untrained subjects were entirely "without knowledge." It is needless to add that all other usual laboratory precautions were observed, such as eliminating time and space errors by a compensating order of tests, etc. Minor variations of method for special purposes will be described in connection with the different groups of experiments, and the special method used for the determination of the color quality of the negative after-image, used in the tests of group V, will be given with the discussion of that group.

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[13] Criticisms, from the laboratories of Clark and Bryn Mawr Universities (first communicated to the writers orally. For published results see the Psych. Rev. 22, 1915, 110-162), have not been overlooked, but the method was used for lack of a better one. Since the experiments of Groups I and II seem to indicate that the brightness of the contrast ring has very little, if any, effect on the *quality* of the contrast color, which is the point at issue in these tests, any inaccuracies in the method of equating brightnesses probably do not seriously affect the validity of the results.

[14] To these student subjects the writers take this opportunity of expressing their sincere thanks for the time and patience devoted to the work.

The tests made fall into the following main groups:

Groups I and II: to determine the general qualitative relation between the complementary and contrast colors, and the dependence of this relation on the brightness of the contrast ring, and on eye-movement.

Groups III and IV: the influence of artificial adaptation to different colors on the quality of the complementary and of the contrast colors.

Group V: supplementary tests with untrained subjects: the relation between complementary, simultaneous contrast, and negative after-image colors.

§3. Experiments. Group I.

The experiments of this group were in several respects rather rough tests, and should therefore be considered as preliminary. The results are given here for two reasons: first, because so far as the methods used agree, these results are essentially the same as the findings of later, more careful experiments; and second, because the tests of this group and of group II include some material not found in the later work. At the outset we hoped to be able to solve simultaneously two problems: the primary problem of the relation of contrast colors to complementary colors, and the secondary one of the possible dependence of the quality of the contrast color on the brightness of the black and white contrast ring in comparison with its colored background. Later, for various reasons, this second problem was dropped. The tests of this and the following group are therefore the only ones in which contrast rings of varying degrees of brightness were used. The observers of this group were three, C., K. and F. For each of these subjects a determination was made of the complementary and the simultaneous contrast colors of Hering red, yellow, green, and blue, and of the Milton-Bradley yellow. This last color was included because for most observers it is almost the exact complementary of the Hering blue, while the Hering yellow is apparently somewhat too greenish. The difference between complementary and contrast colors comes out therefore especially strongly by using the Hering blue and Milton-Bradley yellow papers, as will be seen from an examination of the results in the following table. With the one exception of the Milton-Bradley yellow all papers used are the Hering standard colors. The first column on the left gives the color whose complementary and contrast colors are being determined. The next column shows the varying amounts of white in the contrast ring. The rest of the ring was black. Then follows for each of the three observers the relative amounts of the two primary colors needed to make the complementary, and the relative amounts of the same (or different) two colors needed to match the apparent color of the contrast ring. In the last column for each observer is stated the direction of the difference between complementary and contrast colors. This form seems the most convenient one for a comparison of results. For example, if for observer C. the average complementary color equation is 52°B + 140°R + 168°G = 88°W + 272°N (black), then the complementary of red lies between blue and green in the proportion of 52 of the former to 168 of the latter, or the ratio of blue to green is 0.31. The equations for the contrast colors are treated similarly. For observer C. the color induced by a ring of 40° white *plus* 320° black on a red disk is matched by a disk composed of 9.5°B + 19.5°G + 22.5°W + 308.5 N. The contrast color is therefore an unsaturated bluish green, in which the blue and green appear in the proportions of 9.5 :19.5, or 0.49. The table of results follows:

		Observer C			Observer K			Observer F		
Color	Degrees of W. in contrast ring	Complementary	Contrast	Direction of Difference	Complementary	Contrast	Direction of Difference	Complementary	Contrast	Direction of Difference
R	40	$\frac{B}{G} = 0.31$	$\frac{B}{G} = 0.49$	bluer	$\frac{B}{G} = 0.35$	$\frac{B}{G} = 0.38$	(bluer)	$\frac{B}{G} = 0.34$	all B	bluer
	←									
	60		0.66	bluer		0.31	(greener)		all B	bluer
	80		0.87	bluer		0.39	(bluer)		all B	bluer
	100		0.88	bluer		0.36	(bluer)		all B	bluer
Y (M. B.)	200	$\frac{G}{B} = 0.03$	$\frac{R}{B} = 0.42$	redder	$\frac{G}{B} = 0.04$	$\frac{R}{B} = 1.10$	redder	all B	$\frac{R}{B} = 0.74$	redder
	220		0.39	redder		1.13	redder		0.47	redder
	←									
	240		0.43	redder		1.02	redder		0.47	redder
	260		0.43	redder		1.07	redder		0.50	redder
Y (H.)	200	$\frac{R}{B} = 0.19$	$\frac{R}{B} = 0.51$	redder	$\frac{R}{B} = 0.22$	$\frac{R}{B} = 1.30$	redder	$\frac{R}{B} = 0.18$	$\frac{R}{B} = 0.54$	redder
	220		0.48	redder		1.31	redder		0.42	redder
	240		0.60	redder		1.30	redder		0.38	redder
	260		0.62	redder		1.29	redder		0.48	redder
	←									
G	100	$\frac{B}{R} = 0.37$	$\frac{B}{R} = 0.59$	bluer	$\frac{B}{R} = 0.43$	$\frac{B}{R} = 0.28$	(redder)	$\frac{B}{R} = 0.42$	$\frac{B}{R} = 0.48$	(bluer)
	120		0.64	bluer		0.40	(redder)		0.34	(redder)
	←									
	140		0.64	bluer		0.45	(bluer)		0.32	(redder)
	160		0.61	bluer		0.42	(redder)		0.34	(redder)
B (with M. B. Y)	80	$\frac{G}{Y} = 0.04$	$\frac{G}{Y} = 0.81$	redder	$\frac{R}{Y} = 0.06$	$\frac{R}{Y} = 0.87$	redder	all Y	$\frac{R}{Y} = 1.02$	redder
	←									
	100		0.65	redder		0.81	redder		0.97	redder
	120		0.57	redder		0.60	redder		0.51	redder
	140		0.61	redder		0.55	redder		0.82	redder
B (with H. Y)	80	$\frac{R}{Y} = 0.28$	$\frac{R}{Y} = 1.24$	redder	$\frac{R}{Y} = 0.31$	$\frac{R}{Y} = 1.82$	redder	$\frac{R}{Y} = 0.25$	$\frac{R}{Y} = 1.65$	redder
	←									
	100		1.04	redder		1.36	redder		1.29	redder
	120		0.77	redder		1.09	redder		1.25	redder
	140		0.90	redder		1.15	redder		1.49	redder

Each of the values given in this table is an average of only two determinations.[15] Small variations are therefore of no significance,[16] but the general tendency is unmistakable, and is in agreement with the findings of Tschermak. In all cases, for all three observers, the contrast color has a tendency to be either redder or bluer than the complementary. The only exception is the second value given for the contrast of R. with the subject K., where the difference involved is so slight as to be without significance. The divergence between contrast and complementary color is, however, much more striking with yellow and blue than it is with red and green. Indeed, it practically disappears for both red and green in the case of the observer K., and for green with observer F. For blue and yellow, on the other hand, it is marked for all observers, so much so that the contrast color of blue is orange, or reddish-orange, rather than yellow, and the contrast of yellow is violet. And this is true in spite of the fact that blue and Milton-Bradley yellow are exactly complementary for one observer, and are made so for the other two observers by the addition of a very slight amount of *green*. Hering yellow, as noted above, needs to be changed by the addition of a slight amount of red to make it complementary to the Hering blue, but very much more red must be added before it matches the contrast color induced by the same blue.

So far, then, these preliminary experiments substantiate Tschermak's results that the contrast color is redder or bluer than the complementary, and add to his conclusions that the difference is large in the case of blue and of yellow, while usually very small for red and for green. Later experiments (Groups III and IV) were designed to test Tschermak's explanation of the difference as due to the (supposedly) purplish adaptation of the eye in ordinary daylight. Before passing on to those, however, it may be worth while to devote a little space to the other two questions to which the present group of experiments was designed to give at least tentative answers. Those questions are:

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[15] For this reason and because of the preliminary nature of the tests, mean variations are not given.

[16] Parentheses in the table indicate differences between contrast and complementary colors which are certainly too small to be significant.

First, does the quality of the contrast color vary with variations in the brightness of the contrast ring?

Second, does the amount of contrast induced vary with the brightness of the ring; in other words, is it true that "the contrast effect is greatest when there is no simultaneous light contrast"?[17]

The first of these questions was suggested by the nature of our problem itself; the second arose out of the fact that our laboratory students, using Professor Titchener's manual and textbook, had often been troubled by finding their experimental results not in accord with this "third law of contrast" as quoted above, and this opportunity for testing the law seemed too good a one to be passed by. Unfortunately, however, owing to a mistake of the experimenters, the variations in brightness of the contrast rings were not distributed evenly on either side of the zero point, or point of no brightness contrast. The arrows in the second column of the table already given (p. 15) indicate the points at which brightness contrast between gray ring and colored background has been eliminated, as tested by the flicker method.[18] Owing probably to this defect, or else to the small number of tests made for each average, or possibly to real individual differences, the results for the three subjects agree in their answers to neither of the questions stated above.

In regard to the first question, the dependence of the quality of the contrast color on the brightness of the contrast ring in relation to the brightness of the inducing background, the results are as follows:

For the subject C.: the anomaly (*i.e.,* the difference between contrast and complementary colors) is greatest where there is least brightness contrast in the cases of the colors blue, green, and Hering yellow. With red the anomally is greatest with the lighter contrast rings. Milton-Bradley yellow shows irregular results.

For the subject K.: the anomaly is greatest with the elimination of brightness contrast for the colors blue and Milton-Bradley yellow. Hering yellow shows only slight variations for the different brightnesses, and for this subject the anomaly practically disappears with red and green.

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[17] Titchener, E. B. *Text-Book of Psychology,* 1909, p. 76.

[18] *Cf.* above, p. 12, footnote.

For the subject F.: the results are too irregular to allow of any generalizations.

The only possible conclusion, therefore, seems to be that there is a slight tendency for the difference between contrast color and complementary to increase with a decrease in the brightness contrast between contrast rings and background. In spite of the indefiniteness of this statement, however, the fact must be emphasized that with all three subjects, for the colors blue and yellow where the difference between contrast color and complementary is marked, that difference is independent of any variation in the brightness of the constant ring. The *amount* of the anomaly varies somewhat for the different brightnesses of the gray ring, but it never disappears and is never reversed, and the variations themselves are relatively slight when compared with the large differences between contrast and complementary colors. Whatever the brightness of the contrast ring, the contrast color of blue is always orange, and the contrast of yellow, violet. The conclusion seems justified, then, that the difference between contrast and complementary colors, at least in the cases of blue and of yellow, is independent of any difference in brightness between contrast-inducing and contrast-suffering surfaces.

With regard to the second question stated above, the dependence of the *amount* of contrast color on the presence or absence of simultaneous brightness contrast, the results are somewhat irregular, but are in general in at least partial agreement with the generally accepted law that color contrast is greatest when brightness contrast is eliminated. The amount of contrast is obtained by adding together the number of degrees of contrast color in the original equations obtained. This gives the following:

Table II

Color	Degrees of W in contr. ring	Contrast color	Amount of Contrast		
			C	K	F.
R	40	G + B	29.0	25.5	9.5
	←				
	60		50.5	34.0	8.0
	80		70.0	25.0	5.0
	100		73.5	30.0	14.0
Y (M.B.)	200	B + R	132.7	62.4	50.5
	220		136.4	68.3	53.5
	←				
	240		136.3	69.3	66.0
	260		137.7	81.3	78.0
Y (H.)	200	B + R	114.5	76.0	116.0
	220		132.5	77.5	92.0
	240		146.5	88.5	134.5
	260		147.0	88.0	123.0
	←				
G	100	R + B	92.0	46.0	80.0
	120		119.0	54.0	71.3
	140		114.0	53.0	82.0
	160		101.5	52.0	89.5
B (with M.B.) Y)	← 80	Y (M.B.) + R	95.0	64.5	70.5
	100		108.0	75.0	73.0
	120		100.0	78.5	79.5
	140		108.5	68.0	88.5
B (with H. Y)	← 80	Y (H.) + R	108.5	76.0	65.0
	100		114.0	82.5	99.5
	120		103.5	74.0	121.5
	140		111.0	73.0	81.0

The abbreviations here are the same as those already used in Table I. Again the arrow in column 2 indicates the point at which brightness contrast between gray ring and colored background is eliminated. The law of greatest color contrast when brightness contrast is eliminated seems to hold here only to a certain extent. It is apparently partially counteracted by another tendency, namely, for the lighter rings to suffer greater contrast effect than the darker ones. Owing to the faulty nature of the brightness series for the different colors, the two laws (if the second tendency may be called a law) sometimes work together and sometimes cut across each other. The relative strength of the two laws, and indeed the existence of the second tendency as a general law, can be determined only by further experiments planned for the purpose.

§ 4. Experiments. Group II.

In the experiments of Group I, Tschermak's method in regard to the use of a fixation point was not followed, but the eyes of the observer were allowed to move freely from one disk to the other as he formed his judgments. Tschermak suggests that with free eye-movement after-images may set in and influence the results. Accordingly, in Group II the experiments of Group I were repeated with no other change than the introduction of a fixation-point midway between the two disks,[19] and thereby the elimination of eye-movement. The results are so very similar to those already reported in the experiments of Group I that it seems useless, especially in the case of such rough tests, to give them in detail. They show the same main conclusion as that reached in the preceding experiments, namely, that the contrast color is always either redder or bluer than the complementary. The difference is striking for blue and for yellow, often rather insignificant for red and for green. The only case where the two sets of results are at variance is in the case of the color green for the subject C. In Table I for this subject the contrast color of green is a purple somewhat bluer than the complementary; in the present group of experiments it is slightly redder. It will be noted, however, that in Table I for both the other observers the color green gives irregular results, the contrast color being sometimes redder, sometimes bluer than the complementary. This is, of course, exactly what one would expect if, as Tschermak concludes, and as our results seem to indicate, the physiologically induced contrast of any color has a tendency to take on a more purplish tone than the complementary. Since the complementary of the Hering green is itself purple, its contrast should be the same color, and the irregular variations in the direction of red or of blue are very probably due to accidental variations not eliminated in these rough tests.

The main conclusion of these two groups of experiments is, then, that both in the case of foveal fixation of the colors to be compared, with free eye-movement (Group I), and in that of the elimination of eye-movement with slightly extra-foveal vision

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[19] *Cf.*, above, p 7.

(Group II), the contrast color tends to diverge from the complementary in the direction of purple, with the result that the contrast colors of blue and of yellow are much redder than their respective complementaries, the contrast of red is somewhat bluer than its complementary, and the contrast of green is approximately the same as its complementary. The results are thus far in full agreement with those of Tschermak, though, as already noted, his emphasis was on the difference between "opposite" color and complementary, rather than on that between complementary and contrast color.

Before taking up the experiments testing Tschermak's explanation of the anomaly, brief mention may be made of the results of the present group of experiments in regard to the two other questions under consideration in this and the preceding group, *viz.*: the dependence of the quality and of the amount of contrast color on the presence or absence of simultaneous brightness contrast. The results of this group of experiments show somewhat greater irregularities than those of Group I, the simple explanation probably lying in the fact that none of the three subjects tested had had any particular practice in the difficult task of looking at one thing while paying attention to another. The judgments with a fixation-point midway between the two disks to be compared were, therefore, more difficult and were made with much less subjective certainty, in these early experiments, than in the tests without the fixation-point. Gradually, however, all the subjects grew more and more accustomed to the unnatural conditions of the experiment, and in the tests of the later groups the two subjects who served throughout, C. and K., thought the judgments with the fixation-point fully as easy if not easier than those where free eye-movement was allowed.

So far as the values of the contrast color for the different brightnesses of the gray ring show any regularity, they agree with the results of the experiments of Group I: the anomaly shows some tendency to increase with decrease in brightness contrast between contrast-inducing and contrast-suffering surfaces. The values are, however, too irregular to justify any detailed treatment.

The *amount* of contrast induced for the different brightnesses of the contrast ring seems to depend on the combined effect of the two tendencies already noted in Group I (p. 19). The first tendency is that expressed by the standard law of greatest color contrast where there is no simultaneous brightness contrast. The second tendency is for the lighter gray rings to suffer more contrast than the darker ones. The first tendency seems to be especially strong with observer C., the second with observer K. Whether this is a real individual difference or is due to accidental variation; in fact, whether or not the second "tendency" noted above is a real law, could be tested only by further, more exact experiments. The problem was dropped at this point in order that sufficient time might be devoted to the question of the quality of the contrast color, and to a testing of Tschermak's explanation of its deviation from the complementary.

Thus the conclusions reached by the experiments of Groups I and II are as follows:

1. That the color induced by simultaneous contrast, for the three primary colors, red, blue, and yellow, is not the same as the complementary color. The contrast color of red is somewhat bluer than the complementary, and the contrast colors of blue and of yellow are much redder than their respective complementaries. That of green, on the other hand, is approximately the same as its complementary. This may be expressed by saying, with Tschermak, that the contrast color tends to be more purplish in tone than the complementary.

2. That the direction, and to a large extent the amount of the anomaly, is independent of brightness contrast between contrast-inducing and contrast-suffering areas. If anything, the anomaly is greatest when brightness contrast is least.

3. That the amount of contrast induced on the gray ring seems to depend on the simultaneous operation of two tendencies: (*a*) for the color contrast to be greatest when brightness contrast is eliminated; (*b*) for the lighter gray rings to be more subject to contrast effects than the darker ones.

4. That the above conclusions apply equally to foveal vision with free eye-movement, and to slightly extra-foveal vision with eye-movement eliminated.

§ 5. Experiments. Group III.

As noted in § 1, the tendency toward purple shown by both complementary colors and negative after-images in comparison with "opposite" colors was explained by Tschermak, following Hering and Hess, as due to the purplish adaptation of the eye in ordinary daylight, and this hypothesis was tested by experiments with artificial adaptation, which have already been criticised.[20] Whether such an explanation could account for the similar difference, noted but unemphasized by Tschermak, between complementary and contrast colors, was the next problem which presented itself for our consideration. If the adaptation hypothesis is correct, the anomaly in case of the colors yellow and blue should increase with artificial adaptation to red or purple, and should decrease or be reversed with adaptation to green or yellow-green. For the color red, the anomaly should increase with adaptation to blue or purple, and should decrease or be reversed with adaptation to yellow or yellow-green. For the color green the existence of the anomaly (*i.e.*, a difference in quality between complementary and contrast colors) is doubtful.[21] The best method of testing the adaptation hypothesis is evidently, therefore, that used by Tschermak, namely, to repeat with artificial adaptation to different colors all or a part of the tests already made with normal adaptation. Since the anomaly was strongest for the colors yellow and blue, we confined our work in the present group of tests to artificial adaptation to red and to yellowish-green only. The writers were the only observers available for these tests, since the work demanded more consecutive time than the undergraduate subjects could be asked to give. No attempt was made to study further the influence of brightness contrast or of eye-movement on the contrast color, but the experiments were concerned solely with the study of the respective qualities of complementary and contrast colors under normal, red, and green adaptation, with all other conditions as constant as possible. Eye-movement was, therefore, eliminated by the use of the fixation point, and only one ratio of black and white in the contrast ring was used for each color—that producing a gray of equal brightness to the colored background, as tested by the flicker method.[22] This group, therefore, contains determinations of complementary and contrast colors made with normal, with red, and with green adaptation (rotating according to a compensating program).

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[20] *Cf.*, above, pp. 9-10.

[21] *Cf.*, above, p. 21.

The artificial adaptation was obtained, as by Tschermak, by wearing for two hours before and during the experiment colored glasses of red or of green. The glasses used in this group of tests were obtained from an optician and were mounted in ordinary optician's frames. Unfortunately, however, this method is open to several objections. In the first place, normal daylight could reach the eye around the sides of the glasses, therefore the adaptation cannot be considered complete. In the second place, the red and green glasses turned out to be of very unequal strength, though we tried to obtain them as nearly alike as possible.[23] In the third place, because of the greater strength of the green glass, the adaptation to green was, even subjectively, not absolutely complete at the end of the two hours which preceded the actual tests. For these reasons, the experiments of this group should be considered in the light of rough preliminaries to those of the next group, where the colored adaptation was obtained by a more accurate method. The results are included here because they disagree radically with the results of Tschermak obtained under somewhat similar conditions, but agree very closely with the results of the more accurate experiments of Group IV. The values of the complementary and contrast colors of red, Milton-Bradley yellow, Hering yellow, green, and blue for the two subjects C. and K. under conditions of normal, of red, and of green adaptation are given in the following tables. Each ratio as given here is computed from the average of four determinations. Variations in the single determinations are not given, since these tests are preliminary to the more accurate ones of the next group.

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[22] *Cf.*, above, p. 12.

[23] As tested later by the Lovibond tintometer the green glass was found to be equal to 0.5 units of blue plus 7.5 units of yellow, the red glass to 1.0 unit of red.

TABLE III. OBSERVER C.

Color	Adaptation	Compl.	Contr.	Direction of Difference
R	Normal	$\left\{\frac{B}{G}\right\} = 0.42$	$\left\{\frac{B}{G}\right\} = 1.06$	bluer
	Red	0.38	0.84	bluer
	Green	0.39	1.05	bluer
Y (M.B.)	Normal	$\left\{\frac{G}{B}\right\} = 0.02$	$\left\{\frac{R}{B}\right\} = 0.53$	redder
	Red	0.06	0.41	redder
	Green	0.01	0.33	redder
Y (H.)	Normal	$\left\{\frac{R}{B}\right\} = 0.20$	$\left\{\frac{R}{B}\right\} = 0.81$	redder
	Red	0.19	0.59	redder
	Green	0.20	0.52	redder
G	Normal	$\left\{\frac{B}{R}\right\} = 0.47$	$\left\{\frac{B}{R}\right\} = 0.28$	redder
	Red	0.49	0.58	bluer
	Green	0.42	0.39	redder
B (with H.Y)	Normal	$\left\{\frac{R}{Y}\right\} = 0.33$	$\left\{\frac{R}{Y}\right\} = 1.82$	redder
	Red	0.28	1.33	redder
	Green	0.30	1.06	redder

TABLE IV. OBSERVER K.

Color	Adaptation	Compl.	Contr.	Direction of Difference
R	Normal	$\left\{\frac{B}{G}\right\} = 0.38$	$\left\{\frac{B}{G}\right\} = 0.61$	bluer
	Red	0.38	0.56	bluer
	Green	0.29	0.58	bluer
Y (M.B.)	Normal	all blue	$\left\{\frac{R}{B}\right\} = 0.62$	redder
	Red	" "	0.60	redder
	Green	$\left\{\frac{G}{B}\right\} = 0.02$	0.66	redder
Y (H.)	Normal	$\left\{\frac{R}{B}\right\} = 0.18$	$\left\{\frac{R}{B}\right\} = 0.62$	redder
	Red	0.23	1.14	redder
	Green	0.20	0.71	redder
G	Normal	$\left\{\frac{B}{R}\right\} = 0.40$	$\left\{\frac{B}{R}\right\} = 0.26$	redder
	Red	0.45	0.26	redder
	Green	0.36	0.28	redder
B (with H.Y.)	Normal	$\left\{\frac{R}{Y}\right\} = 0.28$	$\left\{\frac{R}{Y}\right\} = 1.86$	redder
	Red	0.35	1.62	redder
	Green	0.29	0.92	redder

The results evidently do not verify the adaptation explanation of the difference between contrast color and complementary, since that difference persists in the same direction for red, for green, and for normal adaptation. On the one hand, there is no trace of such a reversal of the anomaly with yellowish-green adaptation as that reported by Tschermak; and on the other, the anomaly for blue and yellow is not appreciably increased by red adaptation, as it should be according to the Tschermak hypothesis. According to that theory, it will be remembered, both complementary and contrast colors, but especially the latter, should become more reddish with red adaptation, and more greenish (or less reddish) with green adaptation. Out of the ten complementary colors determined (five for each observer), there is no case in which the color is more red (or less green) than normal with red adaptation, and more green (or less red) than normal with green adaptation; and of the ten contrast colors determined there is only one case in which this is true (the contrast of Hering yellow for observer K.). The only general tendency that can be detected is for the contrast colors to become somewhat less reddish than normal with *both red and green* adaptation,—a paradoxical enough result! The only possible explanation that would seem to suggest itself is that, since both red and green glasses decrease the amount of light reaching the eye, the *brightness* of the light to which the eye is adapted has more effect on the color quality of the contrast colors than has the *quality* of that light. The differences between daylight and dark adaptation reported by Hering and Hess might, therefore, be explained on some other ground than that daylight adaptation is really adaptation to reddish-blue, as Tschermak supposes. It is, of course, conceivable that the *amount* of light reaching the eye causes qualitative, as well as quantitative, differences in the retinal processes involved, in other cases than the well-known one of twilight vision. At any rate, it is evident that the effect on both complementary and contrast colors of artificial adaptation to different colored lights can be studied adequately only under conditions of equal brightness of light for the different colors. These conditions the experiments of the next group attempted to fulfill.

§ 6. Experiments. Group IV.

These tests repeat those of the preceding group under more exact experimental conditions. The writers, C. and K., again acted as observers. As in the experiments of Group III, eye-movement was eliminated by the use of a fixation point midway between the two disks to be compared, and the contrast ring for each color was of the same brightness as its colored background. The differences in method between these tests and those of the preceding group were the following:

1. Tests were made with artificial adaptation to each of the four primary colors, red, green, blue and yellow, instead of to the first two only.

2. The colored glasses were provided by the Lovibond Tintometer Co. of Salisbury, England, and each glass was of one unit's strength, as measured by their scale. In this way we hoped to reach approximate equality in the brightness of the different colors.

3. The glasses were mounted in black automobile goggle frames which allowed no light to reach the eye except that passing through the colored glass.

4. Adaptation with these glasses was subjectively complete in less than half an hour. The glasses were, therefore, worn for only three quarters of an hour before the experiment, and of course during its progress.

5. Since all these colored glasses change the quality of light reaching the eye by reducing its amount, normal daylight adaptation gives, of course, a different condition of brightness adaptation than do the colored glasses. A fifth pair of goggles was, therefore, made up with glasses of the Lovibond neutral gray of one unit's strength.[24] In the table following, adaptation to these

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[24] According to the Lovibond calculations, as we understand them, these glasses should give colors and gray of equal brightness. Actually, however, the green and gray glasses are (both subjectively and physically) darker than the others, since they are not single glasses but are obtained by combinations of the others. Each of the red, yellow, and blue glass absorbs a certain amount of all light except that of the given color. Green, which is made up of the blue and yellow glasses, thus gives a double subtraction of light, and gray (blue + yellow + red) a triple subtraction. It is probable,

glasses is called gray (A) adaptation, while that to ordinary daylight is called normal (N) adaptation.

6. The use of the Milton-Bradley yellow was omitted as an unnecessary expenditure of time, since the Hering yellow brings out the anomaly just as clearly, by the relative *amounts* of red used in the complementary and contrast colors, if not as spectacularly, by the actual reversal of green in the complementary to red in the contrast. All papers used in these tests are, therefore, the Hering colors.

7. In the earlier experiments, the contrast color had seemed to both observers to change, both in amount and in quality, during the time required for the formation of a judgment, becoming both stronger and redder with long fixation. We had no time to test the point by actual experiment, but in the tests of this group adopted, as a precautionary measure, a uniform fixation time, for both complementary and contrast colors, of five seconds. This particular time was chosen as long enough for the formation of an easy judgment, but not so long as to cause fatigue.

Each ratio given is computed from the average of four observations. Mean variations are given in parentheses after each average.

Again the results are negative in regard to the dependence of the difference between contrast and complementary color on the color to which the eye is adapted at the time of observation. For both subjects, with all six kinds of adaptation, the contrast color of red is bluer than its complementary (slightly so for K., very much so for C.), the contrasts of yellow and of blue are much redder than their complementaries, and the contrast of green is approximately the same as its complementary (somewhat redder for one subject, equal for the other). It will be

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therefore, that we should have had more nearly equal brightness conditions if we had used, for example, blue, yellow, and red of 6 units' strength each; green made up of 3 units of blue and 3 units of yellow; and gray of 2 units blue + 2 units yellow + 2 units red. The actual amounts of light of all colors reaching the eye would then have been equivalent. At least, however, the use of the Lovibond units at their face value gives three colors, red, yellow and blue, of equal brightness.

TABLE V

Color	Adaptation	Observer C			Observer K		
		Complementary	Contrast	Direction of Difference	Complementary	Contrast	Direction of Difference
R	N	$\frac{B}{G}=0.42$ (.03)	$\frac{B}{G}=1.12$ (.18)	bluer	$\frac{B}{G}=0.42$ (.04)	$\frac{B}{G}=0.51$ (.04)	bluer
	R	0.37 (.03)	1.27 (.25)	bluer	0.40 (.03)	0.76 (.36)	bluer
	Y	0.41 (.04)	1.05 (.31)	bluer	0.37 (.05)	0.68 (.38)	bluer
	G	0.41 (.04)	1.30 (.24)	bluer	0.43 (.04)	0.59 (.28)	bluer
	B	0.42 (.05)	1.24 (.17)	bluer	0.44 (.04)	0.64 (.35)	bluer
	A	0.41 (.03)	1.25 (.41)	bluer	0.38 (.06)	0.75 (.25)	bluer
Y	N	$\frac{R}{B}=0.23$ (.03)	$\frac{R}{B}=0.75$ (.24)	redder	$\frac{R}{B}=0.19$ (.03)	$\frac{R}{B}=0.66$ (.13)	redder
	R	0.21 (.04)	0.66 (.21)	redder	0.22 (.03)	0.76 (.28)	redder
	Y	0.17 (.03)	0.52 (.14)	redder	0.20 (.02)	0.86 (.18)	redder
	G	0.20 (.03)	0.60 (.11)	redder	0.25 (.02)	0.94 (.17)	redder
	B	0.23 (.04)	0.71 (.21)	redder	0.20 (.01)	0.74 (.09)	redder
	A	0.20 (.03)	0.60 (.20)	redder	0.21 (.03)	0.88 (.15)	redder
G	N	$\frac{B}{R}=0.46$ (.05)	$\frac{B}{R}=0.43$ (.10)	(redder)	$\frac{B}{R}=0.46$ (.05)	$\frac{B}{R}=0.37$ (.06)	redder
	R	0.42 (.05)	0.45 (.05)	(bluer)	0.43 (.04)	0.26 (.06)	redder
	Y	0.49 (.04)	0.54 (.11)	(bluer)	0.40 (.05)	0.27 (.10)	redder
	G	0.42 (.05)	0.51 (.12)	(bluer)	0.44 (.07)	0.25 (.06)	redder
	B	0.44 (.06)	0.46 (.07)	(bluer)	0.45 (.03)	0.40 (.10)	redder
	A	0.48 (.04)	0.44 (.07)	(redder)	0.43 (.07)	0.31 (.05)	redder
B	N	$\frac{R}{Y}=0.35$ (.04)	$\frac{R}{Y}=1.86$ (.18)	redder	$\frac{R}{Y}=0.30$ (.05)	$\frac{R}{Y}=1.64$ (.35)	redder
	R	0.31 (.05)	1.61 (.23)	redder	0.34 (.05)	1.81 (.10)	redder
	Y	0.27 (.05)	1.33 (.16)	redder	0.31 (.03)	1.61 (.14)	redder
	G	0.32 (.04)	1.60 (.09)	redder	0.38 (.04)	1.64 (.07)	redder
	B	0.36 (.05)	1.74 (.05)	redder	0.31 (.02)	1.78 (.14)	redder
	A	0.32 (.04)	1.27 (.02)	redder	0.31 (.06)	1.35 (.18)	redder

noticed that, while the two subjects agree rather closely in their determinations of both complementary and contrast colors of blue and of yellow, and of the complementaries of red and of green, they differ very much in regard to the contrast color of red, and somewhat in regard to the contrast of green, observer C. having a tendency to see more blue in the contrast than is seen by K. The same difference between the two observers is shown in Tables III and IV, though it is somewhat less strong there. K. also tends to see the contrast of yellow as a somewhat redder violet than does C. This difference is more marked in Tables III and IV than in Table V. The writers have no explanation to offer for these differences between their observations, but can only call attention to three points: *First,* and most important for our particular problem, that the difference is one of *degree* of anomaly of the contrast color, merely, not of the direction of the anomaly. *Second,* that the judgments of the contrast color are much more difficult and much less certain subjectively than those of the complementary. The contrast ring takes on a peculiarly shimmering, transparent color which is extremely hard to match to the relatively dead, opaque color of the contrast disk. Accordingly, the individual determinations of the contrast colors show far wider variations than do those of the complementaries, as is shown by the mean variations. Some of the differences between the two observers, however, are very much too large to be accounted for on the ground of accidental variations due to the difficulties of judging the contrast color. *Third,* the differences between the subjects can hardly be due to differences in the selective absorption of the pigment of the eye, for, in the first place, both subjects have very dark brown eyes; and, in the second place, the differences between the observers come out in their determinations, not of the physically aroused complementary colors, but of the physiologically aroused contrast colors.

The negative results of the tests of this and the preceding group, in regard to the main point at issue, namely, the dependence of the direction of the anomaly on the conditions of color adaptation at the time of observation, at once suggests a comparison of our results with those of Tschermak. That experimenter found, it will be remembered, that complementary colors, and still more negative after-images, differ from true "opposite"[1] colors by being more reddish or bluish. In other words, the difference found by Tschermak between complementary colors and negative after-images is the same as that shown in our tests between complementary and simultaneous contrast colors. Tschermak reports the anomaly to be reversed for both after-image and complementary colors of blue, but more for the former than the latter, when the eye is artificially adapted to yellowish green. That is, the anomaly is reversed both as regards the quality of complementary and of negative after-image, and as regards the direction of the difference between the two. Tschermak, therefore, explains the normal anomaly (if one may use the expression) as due to the supposedly purplish adaptation of the eye in ordinary daylight. Tschermak's work has already been criticised.[25] Our experiments would seem to show:

1. In agreement with Tschermak's that the complementary color of a given hue is either more reddish or more bluish than its true "opposite," if the Hering colored papers be taken as rough representatives of the "opposite" colors. We made, of course, no attempt to determine the introspectively "opposite" colors.

2. That the simultaneous contrast color, like the negative after-image, is still more reddish or bluish. The difference between contrast and complementary is especially marked with the colors blue and yellow.

3. That, however, this difference between contrast and complementary is not reversed in direction nor significantly changed in amount under conditions of artificial adaptation to red, green, yellow, or blue. This is not a direct disagreement with Tschermak. If his results could be accepted, it would merely indicate that the simultaneous contrast color behaves differently than does the negative after-image.

4. In direct disagreement with Tschermak, these results show no dependence of the quality of the complementary color on conditions of artificial color adaptation. This is what would be expected if the orthodox laws of color mixture are correct.[26] For both observers, the values of the complementary colors obtained under the different adaptations show only small and obviously chance variations.

In connection with the negative results given as (3) and (4) above, it should be noted that the colored glasses used for artificial adaptation in the experiments of this group were very weak. The glasses used in the tests of Group III were stronger, but, as already stated, those experiments were faulty in many ways. Lack of time prevented any further tests with glasses of greater strength under the more exact conditions of the later experiments, and it is, of course, not impossible that such tests would yield new and (though this is hardly probable) radically different results. The writers can, therefore, merely record the fact that within the limits of these experimental conditions, there was found no trace of a dependence of the quality of either complementary or contrast color on the color to which the eye was adapted at the time of the observation.

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[25] *Cf.*, above, pp. 9-10.

[26] *Cf.*, above, p. 9.

So far, in the discussion of results, no mention has been made of the gray adaptation in comparison with normal daylight adaptation. It will be remembered[27] that the gray adaptation was included in order to have a neutral adaptation more nearly comparable in brightness with the different color adaptations used, than in ordinary daylight. In the tests of Group III, there seemed to be a slight indication that, in the case of the contrast color at least, the anomaly decreases somewhat with decrease in the brightness of the light to which the eye is adapted.[28] If this is the case the normal adaptation of these experiments should show the greatest anomaly, that is, the strongest tendency toward purple,[29] and the gray adaptation the least. This is true in only one case, that of the contrast color of blue for the subject C. Evidently, therefore, within the small limits of variation of these tests, differences in brightness adaptation do not cause an appreciable change in the quality of either complementary or of contrast colors. It must be remembered, however, that the differences of brightness in these experiments are slight, and the chance variations in results are relatively large, especially in the case of contrast colors, where the judgments are difficult and subjectively uncertain. It is quite possible, therefore, as Hering and Hess suppose, that brightness adaptation does cause a difference in the quality of complementary or of contrast colors, or of both, and that the differences between them would disappear under conditions of dark adaptation.

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[27] *Cf.*, above, p. 27.

[28] *Cf.*, above, p. 26.

[29] The tendency toward purple will, of course, take the form of a tendency toward blue of the complementary and contrast colors of red, and toward red for those of blue and of yellow.

The main conclusion, therefore, from the tests of this and of the preceding group is that the difference previously noted between simultaneous contrast and complementary colors persists independently of variations in the color to which the eye is adapted at the time of observation. If these experiments are trustworthy, the adaptation hypothesis of Tschermak is evidently inadequate to explain the anomaly. The writers have, however, no other explanation to offer at the present time, and must leave their conclusions in this negative form.

§ 7. Experiments. Group V.

The tests of the first four groups include the main body of the material. These tests are, of course, subject to the criticism that the two principal observers were also the persons who planned the work and conducted the experiments, and it is, therefore, possible that, in spite of all precautions, they are subject to the expectation error. Accordingly, in order to check at least a part of these results, supplementary experiments were made with the four untrained observers, D., H., Ke., and M., who knew absolutely nothing of the problem or of the results previously obtained. These observers, as undergraduates, could give only a very limited time to the work, but in each case it was possible to make several (two to five) determinations of the complementary, the simultaneous contrast color, and also the negative after-image of the four primary colors, red, yellow, green, and blue. The method for determining the first two was essentially that used in the previous work; the only difference being that, instead of the four Hering papers, red, yellow, green, and blue, we used for our equations the necessary colors from the Milton-Bradley series of eighteen spectral hues.[80] For example, a black and white disk can be matched by the Milton-Bradley red mixed with the Milton-Bradley blue-green and green-blue. In this series of papers, then, the complementary of red lies between blue-green and green-blue—nearer the former than the latter, as determined by the amounts of each necessary to make the equation. Similarly, the contrast induced by the red disk is found to be matched by a combination of black and white with blue-green and green-blue in a slightly different proportion. As in the previous work, the disks to be matched were set up on two color-mixers with a fixation-point midway between them. Eye-movement was, therefore, eliminated, and all other conditions were as already described for the experiments of Groups I to IV.

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[80] *Cf.*, the method used by MacGregor and Dix, *University of Toronto Studies* vol. II., No. 3, pp. 23-27.

The quality of the negative after-image was determined roughly by the following simple method. On a neutral gray background were pasted two-inch squares of the eighteen Milton-Bradley hues in spectral order four inches apart. The two tints and two shades of each hue were placed at the same distance respectively above and below the hues. The completed chart thus gave a neutral gray background with colored squares equally distant from each other—horizontally, the eighteen Milton-Bradley hues in spectral order; vertically, five brightnesses for each color. One inch to the right of each square was marked a fixation point. The completed chart was hung in a north-west light across the same room used in the previous work.[31] On a second gray chart were pasted, some distance from each other, 2 inch squares of the four colors, red, yellow, green, and blue.[32] A fixation point was marked one inch to the left of each square. The observer obtained an after-image of a given color by fixating the point to the left of that color on this chart, and then the after-image was projected on the large chart on the neutral gray background between the colors. The observer's task was to determine which of the colors of this large chart most nearly matched the color of the after-image. For example, in one test, subject Ke. decided that the quality of the after-image of red lay between blue-green tint 1, and green-blue, tint 1. Three fixation times were used for inducing the after-image: 30 sec., 1 min., and 2 min.; but, since no qualitative difference could be discovered in the results for the different periods of fixation, they will be treated together in discussing results. This method of determining the quality of the after-image is rough, but it has the advantages of consuming little time, and of being easy to use with untrained subjects, where very exact color matches cannot be expected.

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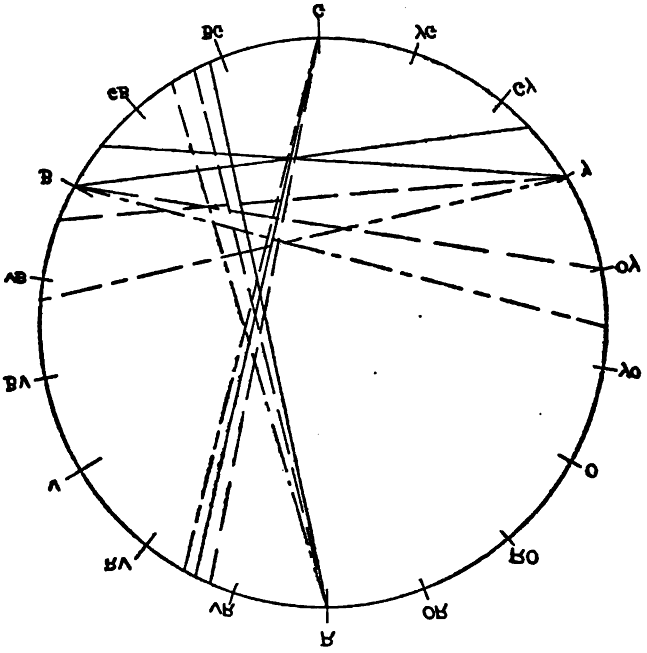
[31] This chart was very bulky, as can easily be imagined. Two inch squares were used as the smallest size that would enable the observer to stand at a comfortable distance from the chart (1 yd. or a little over) and have about the same retinal area stimulated as in the determination of complementary and contrast colors (9.6 cm. seen at a distance of 2 meters). The ratio is only approximate, since the observer had to walk up and down in front of the chart, and it was impossible for her to keep at an exactly constant distance from it.

[32] These were put on the same chart solely for the sake of convenience. Only one color was used at a time.

The results can be given most clearly in graphic form, by arranging the eighteen colors around the circumference of a circle, and indicating by connecting lines the respective positions of the complementary, simultaneous contrast, and negative after-images of each of the four fundamental colors. The straight line (—) indicates the complementary, the broken line (— — —) the simultaneous contrast, and the dotted line (. . .)the negative after-image.



This circular chart gives the results obtained with the subject Ke. The results for the other three subjects, which were very similar to those for Ke., are as follows:

For observer D.—The complementary, simultaneous contrast color, and negative after-image of red are almost identical, all being approximately blue-green.

The same three values for the color green all lie very near together, between red-violet and violet-red.

For the color yellow, on the other hand, the complementary lies between blue and green-blue, the simultaneous contrast color is approximately blue, and the negative after-image lies between blue-violet and violet, nearer the former than the latter.

And for the color blue, the complementary lies between yellow and green-yellow; the contrast color between yellow and orange-yellow, but nearer the latter; and the negative after-image is approximately orange-yellow.

For observer H.—Color red: Complementary, between blue-green and green-blue, nearer the former; contrast, blue-green; after-image, between blue-green and green-blue, nearer the latter.

Color green: Complementary, between red-violet and violet, nearer the latter; contrast, violet-red; after-image, between violet-red and red-violet, nearer the former.

Color yellow: Complementary, between blue and green-blue, nearer the latter; contrast, between the same colors but nearer the former; after-image, between violet-blue and blue-violet.

Color blue: Complementary, midway between yellow and green-yellow; contrast, between orange-yellow and yellow-orange, much nearer the latter; after-image, between yellow-orange and orange, nearer the former.

For observer M.—Color red: Complementary, between blue-green and green-blue, nearer the former; contrast, midway between blue-green and green-blue; after-image, blue-green.

Color green: Complementary, between red-violet and violet-red; contrast, violet-red; after-image, red-violet.

Color yellow: Complementary, between blue and green-blue, nearer the former; contrast, between blue and violet-blue, nearer the latter; after-image, midway between blue-violet and violet.

Color blue: Complementary, between yellow and green-yellow, somewhat nearer the former; contrast, between yellow and orange-yellow, nearer the latter; after-image, between yellow-orange and orange, nearer the latter.

It is evident from these results that the supplementary tests with untrained and unprejudiced subjects, using the Milton-Bradley series of colored papers instead of the Hering, show exactly the same anomaly of contrast and complementary colors in the cases of blue and of yellow as that discovered originally by Goethe and J. Müller, and brought out both by Tschermak and by the experimenters of the present series. Both the simultaneous contrast and the after-image colors of blue and of yellow are distinctly redder than their respective complementary colors. The difference is greater for all four subjects in the case of the negative after-image than in that of the simultaneous contrast color. The differences between complementary, contrast, and after-image colors of red and of green, on the other hand, are too small to be of significance with these few experiments on untrained observers. This negative result in regard to red, however, does not necessarily disagree with the fact that Tschermak found the after-image of red to be bluer than its complementary, and the tests of Groups I-IV in the present series brought out the same difference between the complementary and the simultaneous contrast colors of red. The apparent disagreement is almost certainly due merely to the fact that the anomaly in the case of red is too slight to be evident from the rough tests of this group. On the other hand, even in these tests, the anomaly for blue and for yellow is strikingly apparent, especially in the case of the after-image.

§ 8. Conclusions.

The writers realize very well that the experiments described in the preceding sections leave unanswered many more problems than they succeed in solving. Since, however, it is unlikely that either experimenter will be able to continue this line of work in the near future, it has seemed worth while to report the results even in this unfinished state. In a word, it may be said that the tests are positive as regards the existence of a difference between complementary and contrast colors, both simultaneous and successive, but negative as regards any explanation of the difference. The main points in this conclusion may be summarized as follows:

1. There is a constant difference between complementary and simultaneous contrast colors of the three primaries, red, yellow, and blue. The contrast color of red is bluer than its complementary; the contrasts of yellow and of blue are redder than their respective complementaries. The contrast of green, on the contrary, is about the same as its complementary, showing slight (probably accidental) variations, sometimes toward red, again towards blue (Experiments, Groups I-V). The same anomaly is seen to a still greater degree in the case of the after-images of blue and of yellow, and probably to a slight degree in the case of red (Group V and experiments of Tschermak). This conclusion agrees with that of Tschermak that the contrast color differs from the complementary by tending toward purple.

2. The anomaly of the simultaneous contrast color remains constant in direction with variations in brightness contrast between contrast-inducing and contrast-suffering surfaces. Its amount is probably greatest when brightness contrast is eliminated (Groups I and II).

3. This anomaly does not depend upon after-images induced by eye-movement, since it persists both with foveal vision and free eye-movement, and with slightly extra-foveal vision and elimination of eye-movement (Groups I and II).

4. It is not altered in direction nor appreciably changed in amount by artificial adaptation of the eye to different colors, at least within the limits of color-adaptation used in these experiments (Groups III and IV). It can hardly depend, therefore, as Tschermak supposes the similar anomaly of the after-image to depend, on a purplish adaptation of the eye in ordinary daylight.

The work leaves unsolved the problems:

First, and foremost, of the explanation for the difference between the complementary and contrast colors, including the question of its dependence on the degree of brightness to which the eye is adapted at the time of observation.

Second, the question of the exact relation in quality between negative after-images and colors induced by simultaneous contrast, and the similarity or dissimilarity of their behavior under conditions of artificial color-adaptation.

And as secondary problems suggested during the course of the experiments, but not investigated further:

Third, do lighter surfaces suffer more color contrast effect than darker ones, under equal conditions of brightness contrast between contrast-inducing and contrast-suffering surfaces?

Fourth, to what extent are the amount and the quality of contrast effect influenced by the time of fixation; *i.e.,* what is the temporal rise of the simultaneous contrast color in amount and in quality?

Fifth, do individual observers differ, not only as regards the amount of simultaneous contrast effect which they see under given conditions, but also as regards its quality? If so, what is the explanation of the difference?

It remains only to reiterate that the chief incentive of the writers for reporting the work in its present state is the hope that these experiments, incomplete and rough as they are in many respects, may help the workers in some other laboratory to a solution of one or more of the problems suggested.

A Study of Spatial Associations in Learning And in Recall

BY

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With the Assistance of Marion G. Alexander, Helen Bulkley, Mildred Clark, Josephine N. Curtis, and Grace Hendrie.

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A STUDY OF SPATIAL ASSOCIATIONS IN LEARNING AND IN RECALL

Introduction

This study is a companion-piece to the paper by Jacobs on "Lernen mit äusserer Localization" published in the forty-fifth volume of the *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*. The experiments of Jacobs were made under the direction of Professor Georg Elias Müller in the "psychologisches Institut" of the University of Göttingen a year or two before our own experiments were undertaken. Our experiments were begun in the same laboratory under the same guidance in the academic year 1906-1907 and were continued at Wellesley College in the year 1908-1909. It was in this year that the second writer took part in them and it was in the spring of this year that the experiments of Part I, were completed. The experiments of Part II, were made in the following year. Professor Müller inaugurated both the experiments of Jacobs and our own by serving as subject.

In his first sentence, Jacobs refers to the most common case of the "external localization" of remembered words. When we wish to find a given passage in a familiar book, we are apt to be guided by our recollections of the place where it stood—on the right-hand or on the left-hand page, toward the top or toward the bottom or about the middle. This external localization is distinguished by Jacobs from "internal localization." The external localization of verbal material is the association of words or syllables with objects or with spots in the subject's perceptual field of vision. Internal localization is the association of the words with points in the subject's imaginal or mental field. This inner field (we may infer) is constructed by the subject's imagination; it is not a memory-copy of any given perceptual field and the points at which one localizes the words do not correspond to any points at which they ever stood when one actually read them from a book or paper. If in thinking of the fifty-third canto of *In Memoriam,* I visualize the four stanzas in their proper positions on the right-hand page of my Rolfe edition, this is not internal but is external localization. If, on the other hand, I wish to remember four five-figure telephone-numbers and choose to visualize them as written horizontally in parallel rows, one under another, this would be an instance of true internal localization. The problem of Jacobs was to investigate the advantage of voluntary internal localization in learning material presented to the ear and, therefore, not given in any spatial setting. In the major part of his experiments, nonsense syllables were employed. The series were learned by the method of complete memorizing and, in the later groups of experiments, the firmness of the associations was tested, after varying intervals, by the method of right associates. In half the experiments, the subject, when learning, was required to "localize" the syllables severally upon round black spots arranged in a simple scheme upon a sheet of white paper. In the other half, he was required to close his eyes but was left to his own devices with regard to internal localization, which was neither required nor forbidden. The experiments proved that learning with external localization had a slight but unmistakable advantage, both as regards the number of repetitions necessary for memorizing and as regards the number of right associates obtained after an interval. This showing is the more significant because, as a matter of fact, nearly all the subjects, whether visualizers or not, did actually, when learning with closed eyes, project more or less complete visual images of the syllables into the internal field of vision in a pattern more or less resembling the external localization scheme. Incidentally, Jacobs showed that external localization is rendered difficult by a rapid rate of presentation and that it is of doubtful advantage in learning material with meaning, such as stanzas of poetry.

The first and most important part of our own experiments, the part begun in Göttingen, is in contrast, and at the same time complementary to the experiments of Jacobs in the following points: In the first place, the material—which consisted of "normal" series of nonsense syllables—was presented to the eye and, moreover, was presented in such a manner as to foster to the utmost memories of spatial positions and relations. The subjects were not, indeed, instructed to indulge in external localization but they read the syllables from the sharply demarcated and symmetrically arranged fields of an exposure-tablet and could not well avoid forming place associations. In the second place, we used the method of right associates, pure and simple. Thus, none of our series were supposed to be completely memorized.[1] Our purpose was not directly to test the value of external localization in memorizing,—as Jacobs tested it in terms of necessary repetitions,—but to test it indirectly by gauging, as we shall explain in a moment, the importance of place associations in recall. In the third place, the stimulus-syllables in our test-procedure were exposed under two different conditions. We exposed part of them in the same positions on the exposure-tablet in which they had stood when the subject read the series and we exposed the rest in other places. By this procedure, we sought to determine whether or not syllables exposed in "right" places were more likely to evoke the proper associates than syllables exposed in "wrong" places. If this is a fact, it is an indirect proof of the importance of place associations in learning, for in the cases of right exposure, the place associations would seem to reinforce the associations between the pairs of syllables. Moreover, if syllables presented in the wrong places are relatively unlikely to recall right associates, or if the reproduction time is unduly prolonged, one may well suspect an interference between two sets of associative connections. Suppose, for example, that a test-procedure is in progress in which the subject is required to name the syllable following the syllable exposed. Suppose, further, that the syllable which stood in the third place when the subject read and reread the series is now exposed in the seventh place. This seventh place will suggest the eighth place and this place in turn will tend to suggest the syllable which stood in the eighth place. On the other hand, the third syllable itself will not only tend to suggest the fourth syllable but will also suggest the third place. The third place will suggest the fourth place and this place in turn will also tend to suggest the fourth syllable. If both sets of associations are strong, some blocking of the reaction will be almost inevitable.

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[1] A brief description of this method may be convenient to some readers. The method of right associates is the *Treffer- und Zeitmethode* of Müller and Pilzecker. (*Experimentelle Beiträge zur Lehre vom Gedächtniss,* Zeitschrift für Psych. und Physiol. der Sinnesorgane, Ergänzungsbund I, pp. 3-24.) In this method, series of impressions—say, of nonsense syllables—are presented to the subject a number of times, which should always be insufficient for complete memorizing. After an interval long enough to allow all mental echoes of the series to die away,—an interval perhaps of three minutes, perhaps of twenty-four hours—half the syllables, either all the odd-number syllables or all the even-number syllables, are presented to the subject singly and never in the order in which they originally stood. The subject is required to name in each case the next succeeding or the next preceding syllable according to the half of the syllables selected for presentation. The reproduction time, or the time during which the subject reflects before he responds with "Nichts" or "Don't know," is measured. The results are in terms of four classes of cases, right cases, wrong cases, partly right cases, and zero cases, with the corresponding average reaction times. Cases in which the subject names exactly the syllables which he is required to name are, of course, right cases. Cases in which he names a syllable which has two elements in common with the proper syllable or which contains the proper elements in reverse order are partly right cases. (The three elements of the Müller syllables are the initial consonant, the central vowel or diphthong, and the terminal consonant.) All other cases in which syllables are named are counted as wrong cases. Cases in which the subject names no syllable at all make up the class of zero cases. In the case of a positive reaction, the time actually measured is always slightly greater than the reproduction time proper since it contains not merely this time but also the time necessary for the subject to apprehend the syllable presented, his motor reaction time, and the negligible time spent in overcoming the inertia of the apparatus. The reproduction time is, however, not merely the largest but also the most variable part of this gross reaction time, so that we may safely assume that when the gross reaction time is short, the association is strong and unimpeded, and that when the gross reaction time is long, the association is weak or partially inhibited.

As a matter of fact, the numerical results do show a clear though slight correlation between right exposure and right response and between wrong exposure and incorrect or negative response. They also show a correlation between correct recall of the place in which a stimulus-syllable originally stood and reaction with the proper syllable. This last fact, however, is no proof of the instrumentality of place associations in the recall of the right syllable, since the syllables were learned undoubtedly in and with their spatial settings on the tablet, and it must have been perfectly possible to recall both the place of the stimulus-syllable and the syllable paired with it without having the one memory dependent upon the other. Nevertheless, the introspection of the subjects shows conclusively that place associations did play an important part in the recall of syllables.

The second and less important part of our experiments is supplementary both to the first part and to the experiments of Jacobs. In these experiments, also, we presented normal series of nonsense syllables to the eye and employed the unmodified method of right associates. But whereas in the first part of the experiments all the series were learned from the exposure-tablet, in the second part half the series were learned from a revolving drum. Moreover, during the test-procedure in these latter experiments, all the syllables out of all the series were exposed in the same place upon the tablet, whereas in the earlier experiments they were shown in different places. Thus in half the experiments of this second part, spatial associations were fostered by the use of the exposure-tablet in memorizing, and in the other half, they were minimized by showing the syllables singly in a screen-slit in front of the drum. In the drum series, however, the subjects were left at perfect liberty to have an exposure-tablet in the mental field of vision. Consequently, these experiments are exactly parallel to those of Jacobs, with the substitution of visual for aural presentation and of the method of right associates for Jacobs's combination of this method with the method of complete memorizing. In other words, we strove to determine the value of place associations in memorizing by testing the *degree* to which the two sets of series were mastered with the same number of repetitions, whereas Jacobs sought primarily to find the number of repetitions necessary for *completely* memorizing his two sets, testing incidentally the firmness of the once-perfected associations by the method of right associates. Some of our work miscarried and the results which are worth reporting are not extensive but, as far as they go, they are in entire harmony both with the results of Jacobs and with the data obtained in our own earlier experiments.[2]

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[2] In his opening pages, Jacobs summarizes earlier and incidental observations in regard to the rôle of place associations in memorizing. One of the most important of these observations is that of Müller and Pilzecker (*op. cit.*, p. 221) to the effect that associations of "absolute place" in memorizing syllables, visually presented, may take at least three forms, *viz.*: associations between the several syllables and number words (such as *third* or *eighth*), associations between syllables and the intonations with which the subject may read aloud various parts of the series, and associations between syllables and some visible marker of spatial position (such as the strip of blank paper separating the last from the first syllable upon the exposure-drum). All these associations may properly be called place associations, but only the last class are spatial. Our own experiments and those of Jacobs were entirely concerned with associations of spatial place and the term *place associations* must here be understood to refer exclusively to associations of spatial position.

Although Professor Müller suggested and planned the experiments here reported, the interest of the first writer in spatial associations did not begin in Göttingen but in memorizing blindfold, at Wellesley, series of smells by the reconstruction method. In these experiments, the subject made use not merely of visual images of parts of the table and of her own body but also of percepts and images of the arm-movements involved in placing the scent-bottles at various points on the table. The writer attributes her success in memorizing and reconstructing the series largely to the precision of her place memories. See *Memorizing Various Materials by the Reconstruction Method, Wellesley College Studies in Psychology, Number 1*, Psych. Review, Whole Number 43, pp. 9, 106-107, 116 and 127.

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PART I

SPATIAL ASSOCIATIONS IN RECALL

Method, Material and Apparatus

We have already stated that our experimental procedure was the method of right associates (*Treffer- und Zeitmethode*) of Müller and Pilzecker. In the following paragraphs, the peculiar features of our own procedure will be noted, the apparatus employed will be described and the nature of the nonsense syllables memorized will be exactly specified.

I. *Peculiarities of Our Own Method.*—The topics which should receive mention in a description of our own method are these: (*a*) presentation of material, (*b*) rate and rhythm of repetition, (*c*) number of repetitions, (*d*) the conduct of the test-procedure, (*e*) the statistical treatment of results and (*f*) the requirements made of the subjects.

a. Presentation of Material.—In our own experiments, as we have already noted, presentation was visual and the syllables were read, in time with a metronome, from the sharply demarcated sections of an exposure-tablet. This method of presentation was adopted because, as we have already said, the point at issue in these experiments was the assistance in recall which might be rendered by spatial associations formed during the process of memorizing. The exposure of the syllables in the "squares" of the exposure-tablet made the formation of such associations easy and almost inevitable. The subject read the series line by line from left to right, looking at the tablet through the slit in the fall-screen which will presently be described. The experimenter could govern the time during which the series was visible by opening and closing the slit.

b. Rate and Rhythm of Repetition.—In all our experiments the series were read in strong trochaic rhythm. The rate of repetition for all the American subjects except G. was one syllable to a second and for the subjects M. and G. one syllable to every five-sixths of a second. The untrained American subjects were allowed to read at the comparatively slow rate of one syllable to a second because the irregularities of spelling and pronunciation in the English language make relatively difficult the pronunciation of nonsense syllables presented to the eye as well as the spelling of nonsense syllables presented to the ear.

c. Number of Repetitions.—The number of repetitions was varied from subject to subject since, in the method of right associates, the number should never be so great as to enable the subject to give more than 50 per cent on the average of right answers in the test-procedure. The number was usually diminished for the individual subject as practice increased. The number of repetitions allowed to each subject is given in Table I.

d. The Test-Procedure.—The points which should be noted are: (1) the interval between the learning and the testing of each series, (2) the choice of syllables for presentation, (3) the order in which these syllables were exposed, and (4) the system according to which the syllables were shifted from the positions in which they stood when the series were learned.

1. In all our experiments the interval allowed to elapse between the last presentation and the testing of the subject's mastery of the series was three minutes. During this interval, the subject's attention was distracted; M. read the *Fliegende Blätter;* the other subjects were "entertained" by the experimenters.

2. All our subjects except G. and W. were shown odd-number syllables and were required in each case to name the syllable following. Regressive recall was required of G. and W. because Professor Müller, after serving as subject with progressive recall, suggested that regressive recall would put a higher premium upon spatial associations. Regressive recall was not required of the unpractised subjects, B., D., H., and P. because the task was supposed to be too difficult for them.

3. It is necessary to present the syllables which are to evoke reactions, in an order different from that in which they stood in the original series. If the order is the same, the method virtually

becomes a variety of the prompting method and the process of recall is akin to continuous recitation. Moreover, the syllables which occupy the same numerical positions in the series should not be presented in the same order from day to day,—*e.g.*, the order of presentation should not always be 11, 7, 3, 9, 5, 1,—because the last syllable presented always has a special advantage and a special disadvantage which may or may not compensate. On the one hand, the subject can often arrive at the proper reaction by a process of elimination, by guessing at the right syllable from the syllables he has already named and, on the other hand, the association to be tested is least fresh, being separated by the widest interval of time from the learning process. Therefore, a compensating program of exposures should always be adopted. The program employed in our experiments with series of twelve syllables was copied from the procedure of Müller and Pilzecker and was as follows: Series 1, Syllables 11, 7, 3, 9, 5, 1; Series 2, Syllables 7, 3, 9, 5, 1, 11; Series 3, Syllables 3, 9, 5, 1, 11, 7; Series 4, Syllables 9, 5, 1, 11, 7, 3. And so on in a cycle. The program used with series of eighteen syllables was exactly similar except in the case of the too expert subject G., for whom a special program (unknown to herself), had to be made out. In this case the initial order was 18, 12, 6, 16, 10, 4, 14, 8, 2. This order was, of course, also treated in cyclic fashion.

4. We have already stressed the point that in our experiments it was essential that the syllables should be presented to the eye in different places upon the exposure-tablet, sometimes in the position in which they had been learned and sometimes in new or "wrong" positions. The shifts were made systematically by a compensating program. The places in which syllables had stood during the learning process were called "right places" and all new positions were called "wrong places." No syllable was ever shown directly above or below the right place. As a specimen procedure, part of the program used in the case of M. may be given. This subject learned three series a day. Each series contained eighteen syllables, so that nine syllables were presented in each test-procedure. Of these, either six or three were in wrong places—if six, the series was called "hard"; if three, it

was called "easy." The subject learned either two hard and one easy series a day or *vice versa*, according to an alternating program. On the first day of the experiments actually taken into account, the shifts in the first series were as follows: 1st syllable to 3rd place, 3rd to 5th, 5th to 1st; and 7th syllable to 9th place, 9th to 11th, 11th to 7th. In the second series, they were: 13th to 15th, 15th to 17th, and 17th to 13th. In the third series, 1st to 9th, 9th to 17th, 17th to 1st; and 3rd to 11th, 11th to 13th, 13th to 3rd. On the second day, the shifts were as follows: 1st series, 5th to 7th, 7th to 15th, 15th to 5th; 2nd series, 5th to 9th, 9th to 13th, 13th to 5th, and 3rd to 7th, 7th to 17th, 17th to 3rd; 3rd series, 1st to 11th, 11th to 15th, 15th to 1st. Third day: 1st series, 13th to 11th, 11th to 3rd, 3rd to 13th, and 15th to 7th, 7th to 5th, 5th to 15th; 2nd series, 17th to 9th, 9th to 1st, 1st to 17th; 3rd series, 17th to 7th, 7th to 3rd, 3rd to 17th and 15th to 11th, 11th to 1st, 1st to 15th. Fourth day: 1st series, 13th to 9th, 9th to 5th, 5th to 13th; 2nd series, 11th to 9th, 9th to 7th, 7th to 11th, and 17th to 15th, 15th to 13th, 13th to 17th; 3rd series, 5th to 3rd, 3rd to 1st, 1st to 5th. The program continues in a cyclic series of variations which need not encumber these pages. The cycle of shifts was completed in two more days. This cycle was repeated three times and was once more about half completed. The experiments taken into account extended over twenty days.

e. *Statistical Treatment of Reactions.*—A few words should be said on this point because our sets or "constellations" of cases are not grouped in the ordinary fashion of the method of right associates. Usually the sets are grouped according to the conditions under which the different *series* were learned. In our experiments the sets are formed according to the conditions under which the different *syllables* were presented in the test-procedure. Thus, syllable-reactions belonging to the same series may be included in different sets of cases and syllable-reactions belonging to different series may be included in the same set of cases.

f. Requirements Made of the Subjects.—As we have already said, the subjects were required to read the series aloud in trochaic rhythm to the beats of a metronome. They were told to begin reading the series on the second beat after that upon which it was exposed, and at the end of each repetition to allow two beats to pass before beginning the next. They were not especially enjoined to memorize without the use of auxiliary associations (mnemonic devices). The experimenters believed that the prohibition of such devices does not really inhibit their use even in the case of conscientious subjects, and hoped that a profuse crop of auxiliary associations would be prevented by the rather rapid rate of reading. As will later appear, they were in some degree disappointed in this expectation but they were far from "encouraging" the subjects to make such associations. Special instructions had to be given to the subjects in regard to the use of the lip-key but these instructions need scarcely be repeated here. After each reaction, the subject was asked whether the syllable exposed had been shown in the right place. If he answered "No," he was asked to name the place where it really had stood in the process of learning. He was allowed to answer this question either by giving the number of the rhythmical foot or by saying "the first place," "the ninth place" or the like, or by saying "the second place in the second row" or the like. After the final testing of each series, he was also supposed to state any auxiliary associations which might have come into play. The attention which was thus called to mnemonic devices probably had the unfortunate effect of increasing their number. Lastly, in zero cases (cases in which the stimulus-syllable recalled no other syllable at all), the subject was asked (after each reaction) whether the syllable exposed seemed familiar (*bekannt*) or unfamiliar (*fremd*).

II. *Apparatus.*—The apparatus may be described under two headings: (*a*) the exposure-tablet and (*b*) the apparatus used in measuring reaction time. Under (*b*) the actual manipulation of the apparatus used in the time measurements will also be described.

a. Exposure-Tablet.—This was designed by Professor Müller for these experiments.[8] As used in the Wellesley experiments, it consisted of a metal frame which was supported by two metal uprights upon a wooden base. The frame itself was composed of four sections, each about 38 cm. long and each containing six rectangular openings, 3.8 by 3.2 cm. in size, with the long side horizontal. When the sections were fitted together, the twenty-four openings were separated from one another by narrow margins of metal and formed a very compact field, so that no sweeping eye-movement was required in passing from the right end of one row to the left end of the row below. The field of openings was bordered above, below, and on both sides by a wide margin of the metal. Each of the four plates had a back with a spring-hinge, opening downwards and divided into six compartments into which cards could easily be slipped. When this spring-back was in position, the cards filled the open spaces in the upright part of the metal plate. The whole framework was painted black so that the white cards, upon which the syllables were written, were sharply defined by their borders and had somewhat the effect of four horizontal rows of lighted windows upon a blank and dark wall. The metal plates were supplied at each end of the back with rings which slid up and down upon the uprights of the base. Thus, two, three or four plates could be used at one time according to the length of the series. (Two of the plates were supplied with a wide margin of metal upon one of their horizontal edges.) The level of the field could be slightly altered to suit the convenience of subjects of different heights. The subjects sat at the end of a table with the fall-screen, presently to be described, between them and the tablet. Both the level of the tablet as a whole and its distance from the screen were altered to suit the eye-level and reading-distance of the different subjects. To the end of the table was clamped an adjustable chin-rest modelled after the one in use in the Göttingen laboratory. This description of the exposure-tablet applies in detail only to the one used in the experiments made in the Wellesley laboratory in the years 1908-1909 and 1909-1910. The tablet used in the Göttingen experiments in 1906-1907 was the first of its kind and was inferior to the tablet just described. Upon this tablet, only eighteen syllables could be presented and the openings were much larger, so that the eye-movements involved in glancing from one part of the field to another were considerable.

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[8] The tablet was made by Spindler and Hoyer of Göttingen. See their *Apparate für psychologische Untersuchungen, Preisliste* 21 (1908), p. 157.

b. Apparatus Used in Measuring the Reaction Time.—Throughout our experiments, this apparatus was almost exactly similar to that used by Müller and Pilzecker, and described in detail by these writers.[4] In fact, the fall-screen and lip-key used in the first group of experiments (those made in Göttingen) were the very same screen and key which Müller and Pilzecker had employed. The apparatus used in the Wellesley experiments will be described in some detail, since it differed in a few particulars from that of Müller and Pilzecker, and since the reader may not have the work of these investigators freshly in mind. The apparatus included two electric circuits. In the first, we had a storage battery of about ten volts, a commutator, a simple homemade arrangement for introducing variable resistance, and the electromagnet of the fall-screen. This fall-screen really consisted of two screens, a fixed screen, 75 cm. high and 45 cm. wide, made up of a wooden frame painted black and filled in at the front with black card-board, and a movable screen of the same material which slid up and down in a groove behind the card-board front of the larger screen. Both screens contained slits, 18 cm. from side to side and 5 cm. from top to bottom. When the electric circuit was closed, the current flowed through the coils of an electromagnet at the top of the fixed screen and the fall-screen was held suspended by means of the armature on its top. When the fall-screen was in this position the slit in the fixed screen was covered. At the instant the circuit was broken, the movable screen fell and came to rest in such a position that the slits in the two screens coincided. It was behind this opening that the exposure-tablet was placed In the second circuit, we had a storage battery of two volts, a commutator, a resistance device similar to the one used in the first circuit, a Hipp chronoscope, its control apparatus, the lip-key, and a make-and-break device attached to the side of the fixed screen. The lip-key and make-and-break device were in parallel. The make-and-break device consisted of a small metal lever which, as long as the movable screen was held up, lay across two binding posts on the frame of the fixed screen. When the fall-screen came down, it struck that end of the lever which did not lie across the posts and came to rest upon it, thus raising the other end and keeping the circuit open at this point. This chronoscope circuit could also be made and broken at the lip-key. The connections were so adjusted that the chronoscope ran on the open circuit. The chronoscope-control instrument in the Wellesley experiments was the Ebbinghaus fall-apparatus. The lip-key was held at any desired height by clamps and rods attached to the subject's chin-rest.

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[4] Pp. 3-7. The lip-key used at Wellesley was made by Spindler and Hoyer and is described on page 128 of *Preisliste* 21.

Manipulation of the Apparatus.—In the Göttingen experiments all the work was done by one experimenter, but in the Wellesley experiments the same work was divided between two and sometimes between three persons. When in experiments by the method of right associates the interval between learning and testing (as in our experiments) amounts to only a few minutes, it is important that the testing should proceed as rapidly as possible for, if it drags, the first associations called into play will be much fresher than the last. At the beginning of the test-procedure and between the experiments with the different syllables exposed, both circuits were closed and the slit in the fixed screen was covered by the movable screen. As the first step in each test, an experimenter started the clock-work of the chronoscope. Its buzzing sound warned the subject to raise the lever of the lip-key, thus breaking the chronoscope circuit in the lip-key branch. The next steps were to bring the subject into an attitude of expectancy with the word "Los" or "Now", and about two seconds afterwards to break the magnet circuit at the commutator, thus allowing the movable screen to fall. As soon as the subject reacted, thus closing the chronoscope circuit through the lip-key branch, one experimenter lifted the screen into place and put upon the exposure-tablet the syllable next to be shown, while the other experimenter took the chronoscope reading and recorded the subject's reaction and introspection.

III. *Material.*—In the Göttingen experiments, the material memorized consisted of "normal" series of nonsense syllables made according to the Müller and Schumann rules as adapted by Müller and Pilzecker to series of eighteen members.[5] For the Wellesley experiments comparable series of twelve and eighteen members were made by adapting the Müller, Schumann and Pilzecker rules to the peculiarities of the English language. The rules applied in making these "English" series are given elsewhere in great detail by the first writer.[6] A typical series of eighteen members is the following: *buv, chure, seje, poit, yed, zobe, thas, life, wouz, kane, tish, vox, make, goig, fith, huch, jam, rel.* These series are to be pronounced strictly "by sound,"—*i.e.*, according to the sounds proper to the English letters in the several combinations. Thus, *buv* should rhyme with *dove, chure* with *sure, poit* with *quoit, yed* with *red,* and *zobe* with *robe,* and *seje* should be pronounced like *siege.* When in our laboratory, such series are presented to the eye and read aloud by the subject, mistakes of pronunciation are promptly corrected by the experimenter.

Before we pass to the consideration of the experimental results, we must name the subjects who will figure in them. A description of the subjects as memorizers will be given in connection with the introspective data. The subjects who will be called M., G. and W. are, respectively, Professor Müller, and the two writers of this report. W. was, at the time these experiments were made, an undergraduate pursuing advanced courses both in psychology and in physics. She also served as experimenter upon other subjects and was chief manager of the apparatus. The subjects called B., D., H., and P. were Misses Helen Burr, Harriet Decker, Grace Hendrie and Hortense Peters. These four subjects were draughted in the spring term from a class of students who were completing a first but "three-hours-for-a-year" course in psychology.

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[5] See Müller and Schumann, *Experimentelle Beiträge zur Untersuchung des Gedächtnisses,* Zeitschrift, f. Psych. und Physiol. der Sinnesorgane, 6, pp. 99-106; and Müller and Pilzecker, *op. cit.,* p. 3.

[6] See the study of *Memorizing by the Reconstruction Method* already cited, pp. 19-22. For additional discussion of these series, see p. 110 of these studies.

Details in regard to the amount of work required of the several subjects are as follows: All the subjects worked through a short series of preliminary experiments, made to determine the proper number of readings, the best reading-distance, and so on. With B., D., H., and P., this preliminary series was very short, since the time which they could give to the experiments was strictly limited. In the experiments whose results are here reported, M. worked (as has been said) twenty days, learning three series a day; G., twenty-four days, learning four series a day; W., twenty days, learning three series a day; and B., D., H., and P., thirteen, fifteen, fourteen and sixteen days respectively, learning four series a day. The subjects worked about four times a week in successive weeks. With all except W., the interval between the end of a test-procedure and the first reading of the next series learned on the same day was about two minutes; with W., it was about five minutes.

The reader will easily see in following the discussion of results that they do not furnish data for exactly comparing the facility of the various subjects in memorizing. The conditions imposed upon the several subjects differed much. M., G., and W. learned series of eighteen members; the others, series of only twelve. M. and G. read at a rate faster than that of the untrained subjects and both had trouble in the mere "seeing" of the syllables, whereas all the others had younger and better eyes. M. G. and P. were allowed a much smaller number of readings than the others. Finally, G. and W. were assigned the task of naming the syllable preceding the stimulus-syllable, whereas all the others had the easier task of naming the syllable following. In particular, W. must not be directly compared with the other untrained subjects, since her longer series and the regressive recall demanded of her put her on quite another footing in spite of the large number of readings permitted her. This remark is made because in the pages which follow it is repeatedly necessary to call attention to the small percentage of right associates obtained by W.

Numerical Results

The numerical results furnish data for answering four main questions. (I) Is there a correlation between right and wrong exposure, on the one hand, and the percentages of right, partly-right, and wrong associates and zero cases on the other hand? This question bears upon the effect of an external condition (entirely within the control of the experimenter) upon the subject's ability to recall the proper syllables in the test-procedure of the method of right associates. To this question the effect of right and wrong exposure upon the reaction time in subsidiary. (II) Did the subjects actually remember the places in which the syllables exposed in the test-procedure had stood during the reading of the series? If so, were the subjects more likely to remember the place in which the syllable presented had stood or to recall the syllable which had been paired with it during the learning process? (III) Was right localization of the syllables presented a concomitant of right association? Was wrong localization a concomitant of wrong association? And was failure to localize a concomitant of failure to recall any associate? (IV) Was right localization a concomitant of the feeling that the syllable was familiar and ought to evoke the right associate? These last three questions are concerned, not with the experimenter's exposure of the syllables, but with the subject's localization of them. This was, of course, quite beyond the control of the experimenter, for although she could at will put the syllable presented into a right or into a wrong place on the exposure-tablet, she could in no wise insure the subject's remembrance of the original spatial setting of the syllable.

I. *Were the syllables which were, in the test-procedure, exposed in the places in which they stood when the series was memorized more likely to call up the proper associates than syllables exposed in places in which they had not stood? In other words, did wrong exposure conduce toward wrong or failing association?*

Table I shows the connection between right and wrong exposure and right, wrong and missing associates. In this table,

TABLE I

To Show the Relation of Right and Wrong Responses to Right, Wrong and Missing [illegible]

Subject	Series Length	Repetitions	Syllables Repeated		No. of Stimulus [illegible]	Right Associates		[illegible] Right [illegible]		[illegible]		[illegible]	
			Numbers	Places		%	Time	%	Time	%	Time	%	Time
1	2	3	4	5	6	7	8	9	10	11	12	13	14
M.	18	6, 4	O.	R.S F.S	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
G.	18	4, 3	K.	R.S F.S	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
W.	18	12	K.	R.S F.S	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
B.	12	8	O.	R.S F.S	107 170	[illegible] [illegible]	[illegible] [illegible]	8 7	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
D.	12	8, 6	O.	R.S F.S	[illegible] [illegible]	45 48	[illegible] 2740	0 0	3570 4750	17 24	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
H.	12	8	O.	R.S F.S	150 150	51 49	2800 3880	3 5	2990 6430	10 7	7970 9900	36 38	8840 8400
P.	12	6, 4, 3	O.	R.S F.S	177 176	59 61	2740 3610	4 4	6270 3590	8 6	4810 8950	29 30	7600 9560

the columns are numbered from left to right for convenience of reference. In Column 4, the letters *O* and *E* stand for the words *odd* and *even* and mean that the syllables presented in the test-procedure—the "stimulus-syllables"—were, for a given subject, the odd-number or even-number syllables of the series. In Column 6, the letters *RS* and *FS* stand for the words *right settings* and *false settings* or for *richtige Stellen* and *falsche Stellen*, and refer to the right-place or wrong-place exposure of the stimulus-syllables.[7] Throughout the table, the average numbers of σ have been rounded out to the nearest multiple of ten. On this principle, 3104 would be called 3100 and 3106 would be called 3110. Numbers ending in 5 have been arbitrarily rounded out to the next *higher* multiple of ten.

The first cross-line of the table may be translated into words as follows: The subject Müller read over series of eighteen nonsense syllables at first six times but later four times. The syllables presented in the test-procedure were odd-number syllables. (Thus, this subject was required to name the even-number or succeeding syllables.) In all 275 syllables were shown in the right settings or places. Of these 275, 55 per cent called up right associates in an average time of 3110σ; 3 per cent called up partly right associates in an average time of 9250σ; 13 per cent called up wrong associates in an average time of 15,800σ; and 28 per cent called up no associates at all, although the subject reflected for 15,900σ—*i.e.*, for nearly 16 seconds—on the average.[8]

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[7] *RS* and *FS* should perhaps be replaced in an English report by *RP* and *WP*, but the change would be confusing to the writers who have used the words *rictige Stellen* and *falsche Stellen* from the beginning of the work.

[8] Two points of detail in regard to Table I are these: (1) The numbers of *RS* (rightly exposed) syllables and of *FS* (wrongly exposed) syllables differ slightly in the case of every subject but one, because some syllable exposures had to be thrown out entirely for one reason or another. (2) Not all the *RS* and *FS* cases covered by the percentages in the tables actually have corresponding reaction times, but the difference between the total number of reactions counted and the number timed is negligible. In M.'s case, two reaction times are missing (were not secured or had to be thrown out) under the right associates for the *RS* syllables. The percentage given, 55, represents 151 cases, whereas only 149 were timed, giving the average of

The numerical results represented in Table I fall under two headings: (*a*) percentages and (*b*) average reaction times. The two classes of results will be discussed in order.

a. The percentages of right associates, zero cases, wrong associates, and partly right associates exhibit the following facts:

1. For all the subjects except P. the percentage of right associates (Col. 7) is at least slightly greater for the *RS* (rightly exposed, syllables than for the *FS* (wrongly exposed) syllables. The difference is greatest in the case of M. where it amounts to 9 per cent.

2. For all the subjects except D. the percentage of zero cases (Col. 13) is slightly greater for the *FS* syllables than for the *RS* syllables.

3. For some subjects the percentage of wrong associates (Col. 11) is greater for the *FS* syllables and for other subjects it is greater for the *RS* syllables. Only in the case of D. is the difference considerable. A moment ago it was noted that this subject alone had a larger percentage of zero cases for the *RS* than for the *FS* syllables. Her percentages of wrong cases show a compensating difference, and, if we add together her percentages of wrong and zero cases (see Cols. 11 and 13), we shall find the sum rather greater for the *FS* than for the *RS* cases—53 per cent as against 50 per cent.

4. In no case are the percentages of partly right associates (Col. 9) large enough to merit serious consideration.

5. G.'s percentages of right associates are larger than they should be by the rules of the method. Her number of repetitions should certainly have been reduced to two. The percentages, however, are not too large to allow a difference between the *RS* syllables and the *FS* syllables to appear. Incidentally, it may be

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3110σ, which appears in col. 9. Two reaction times are missing under the wrong associates and three under the zero cases. That is, out of the 275 *RS* syllables counted in the table, seven lack proper reaction times. These figures are typical, and since the differences between the numbers of cases counted in the percentage columns and the numbers counted in the time columns are so very small, they can scarcely be allowed to encumber a table which is already complicated enough. The writers have in their own hands fine-spun numerical data upon this and all similar points.

remarked that M., B., and D. differ from the other subjects in having comparatively large percentages of wrong associates (Col. 11). W., who has many zero cases, has very few wrong associates; G. has few of either; and H. and P. are intermediates between G. and W.

b. In interpreting association-reaction times the following facts should be kept in mind: (1) A large percentage of right associates given in a short average reaction time means that the associations were strong and unimpeded. (2) A large percentage of right cases or a small percentage of zero cases coupled with a long average reaction time denotes a pertinacity on the part of the subject which has given many weak associations sufficient time to function. The high percentage of right associates may be interpreted as meaning a strong set of associations provided that a considerable number of the times which enter into the average are very short. (3) A small percentage of right associates or a large percentage of zero cases combined with a long reaction time means that the associations were either weak or impeded. (4) A small percentage of right associates or a large percentage of zero cases with a short reaction time means that only the strongest of the associations have had a chance to function, or, in other words, that the subject, frightened, self-conscious, indifferent, of hasty mental habit or what not, has taken little time to reflect. (5) A small percentage of zero cases with a short reaction time suggests that out of the set of associations tested a large number have been strong enough to function quickly but that the weaker have missed their chance to function because the subject, if he could not recall the right syllable on the instant, at once gave up the attempt. It need scarcely be said that the wrong-association times are to be interpreted in much the same way as the zero-case times.

The reaction times of Table I can best be discussed subject by subject.

M. With the distinctly smaller percentage of right associates for the *FS* syllables, M. unites the slightly longer association time. This indicates that wrong exposure in the case of M. had a genuinely disturbing effect upon the associations with the *FS* syllables. This inference is confirmed by the fact (not shown in Table I) that M. had 44 very short right-association times in the case of the *RS* syllables as against 31 for the *FS* syllables. As "very short" reaction times are here reckoned those less than 1500 σ. Returning to the table we see that with the somewhat larger percentage of zero cases for the *FS* syllables he combines a much shorter reaction time—the difference amounting almost to two seconds. This clearly indicates that in the case of the *FS* syllables he more readily abandoned the attempt to recall associates. Again in the case of the wrong associates the percentage is greater and the time shorter for the *FS* syllables. This means that the subject, in the case of wrong exposure, was more hasty in naming incorrect syllables. Thus, in the case of M., the figures speak unequivocally for a disturbance of associations by wrong exposure. With no other subject, however, is the disturbance so marked.

G. This subject's times for the *FS* and *RS* syllables differ very little except in the case of the wrong associates (and partly right associates) and the percentages of wrong associates are so small that the difference in the average association times may be purely accidental. With the slightly larger percentage of right associates for the *RS* syllables G. combines the slightly longer association time but into this average time enter fifteen times exceeding 20,000 σ, whereas only six such times enter into the average for the *FS* cases. (M. has only one of these "very long" right-association times and G. has only two "very short" ones.) On the other hand, with the slightly larger percentage of zero cases for the *FS* syllables she also combines the slightly longer reaction time. On the basis of these figures, therefore, it would be impossible to say that G. meditated longer over the reactions to either set of syllables.

W. Virtually the same statements as have just been made for G.'s average times are true for W.'s, excepting that W.'s times differ little even for the wrong associates. It should be noted that W.'s average times are all very short, shorter, on the whole, than those of any other subject. It should also be noted that W. has a larger percentage of zero cases than any other subject and a smaller percentage of right associates than any except B. These facts show that in the case of W. only the strongest associations had time to function. The introspective data must show whether the subject was frightened or whether she belongs to the class of persons who habitually remember quickly if at all, and, therefore, never spend much time in the effort to recall anything which is forgotten.

B. B. like W. has small percentages of right associates with short average times. B., however, has a larger percentage of wrong associates than any other subject and although her percentages of zero cases are not strikingly large, yet her percentages of wrong associates and zero cases taken together exceed those of any other. B.'s times are, like those of W., notably short for both the wrong associates and zero cases. The average times, like the percentages, differ little for the *RS* and *FS* syllables except for the numerous wrong associates. Here the difference amounts to more than a second. These *FS* cases have the longer association time and the smaller percentage of wrong associates. It would seem, therefore, that B. was less hasty in her reactions in the case of the *FS* syllables. This conclusion is not borne out by the figures for the right associates and the zero cases but here the differences in the times may be accidental. B. is obviously the sort of subject who hastily names the first syllable which comes to mind, whereas W. is the sort who hastily answers "Don't know." Curiously enough, neither B. nor W. has many "very short" right-association times (times below 1500 σ); B. has none at all and W. has only four, three for the *RS* and one for the *FS* syllables.

D. This subject resembles M. as regards right and wrong associates although the disturbance created by wrong exposure is less marked. It is worthy of note that D. had ten "very short" right-association times for the *RS* syllables and only two for the *FS*. In her zero cases, however, she combines for the *RS* syllables the larger percentage with the slightly shorter reaction times. The time-difference may well be accidental.

H. This subject resembles M. as regards right associates and zero cases. The disturbance created by wrong exposure, though less marked in the percentages and zero-case times is more marked in the right-association times. Here the *FS* time as compared with the *RS* time is not only much longer but much more variable. The *FS* average represents eight "very long" times (over 20,000σ) and seven very short times, whereas the *RS* average represents only one of the former and three of the latter. In the case of the wrong associates H. combines the much longer reaction time with the smaller percentage for the *FS* syllables. The percentages of wrong associates are, however, relatively small as compared with those of M., B. and D.

P. This subject shows larger differences in her reaction times for the *RS* and *FS* syllables than does any other subject. In every class of reactions (except in that of partly right associates which need not be considered seriously) the reaction times are greater for the *FS* syllables. Wrong exposure, then, evidently spurred P. to a greater effort at recall. In the case of the right associates the longer time is combined with the larger percentage and in the case of the wrong associates the longer time is combined with the smaller percentage. The average *FS* time for the right associates covers seven very long times, whereas the average *RS* time covers only four of these extra long times. The number of very short times represented by the former average is four; that covered by the latter is five. It is probable, then, that P. obtained the larger percentage of right associates in the case of the *FS* syllables because she took the longer time to reflect. In the zero cases, however, the longer time combines for the *FS* syllables with the slightly larger percentage.

We may conclude, therefore, from the data in regard to percentages and reaction times taken together that the seven subjects belong to three different classes as regards the effect of wrong exposure. (1) Neither G. nor W. give clear evidence of association-disturbance although one of these subjects has a very high percentage and the other a very low percentage of right associates both for the *RS* and for the *FS* syllables. (2) M. shows clearly a disturbance of associations as a result of wrong exposure, and D. and H. show the same disturbance somewhat less clearly. (3) P. shows that wrong exposure, whether recognized as such or not, acted as a spur to effort in recall so that any disturbance produced by it was, on the whole, more than overcome. The carelessly reacting subject B. may, though with some uncertainty, be classed with P.

These conclusions receive a certain confirmation from the following figures which represent separately the results for the *FS* syllables which were shown in the "right row," *i.e.,* in the row in which they had stood when the series was learned, and for those exposed in a "wrong" or different row.

Subject	*Wrongly Exposed Syllables*			
	Right Associates with Exposure in		*Zero Cases with Exposure in*	
	Reght Row	*Wrong Row*	*Reght Row*	*Wrong Row*
M.	44%	46%	31%	34%
G.	73	68	21	23
W.	36	37	46	52
B.	27	31	39	32
D.	43	41	29	30
H.	50	49	37	40
P.	54	68	35	24

This scheme shows the following facts: (1) All the subjects, except B. and P., have a larger percentage of zero cases for the wrong-row exposures. (2) Only G., D., and H. have a smaller percentage of right associates for the wrong-row exposures and even in their case the difference is small. It would seem, then, that wrong-row exposure increases the zero cases at the expense of the wrong rather than the right cases, or in other words, that if the syllable is exposed near the place in which it originally stood, the subject is more likely to name some reaction-syllable, right or wrong, than if the displacement is wide. (3) Even W. and more particularly G. show in these figures that they were by no means quite immune to disturbance by wrong exposure. (4) P. and B., the two subjects who, as we have just inferred, were helped rather than hindered by wrong exposure, show a larger percentage of right associates and a smaller percentage of zero cases with wrong-row exposure. In the case of P. the difference is striking.

We may now sum up as follows the evidence in regard to the correlation of right and wrong exposure with right, wrong or failing association: In the case of some subjects, but not of all, wrong exposure did actually conduce toward wrong recall or toward failure to recall any paired syllable. The disturbance, however, was certainly not enormous even in the case of those subjects who were most affected by it. In the case of two out of six subjects, wrong exposure actually increased the final success in recall.

II. *Did the subjects in general remember the places in which the syllables presented had originally stood upon the exposure-tablet? If so, were instances of right localization more common than instances of right association or vice versa?*

The answer to this question is clear and positive. The numerical data are given in the following scheme:

Subject	*No. Syllables in R S.*	*Per Cent Rightly Localized*	*Per Cent Right Associates*	*No. Syllables in FS.*	*Per Cent Rightly Localized*	*Per Cent Right Associates*
M.	275	67	55	277	44	46
G.	424	92	73	420	91	70
W.	274	94	39	258	86	37
B.	167	72	30	170	42	29
D.	163	88	45	162	62	42
H.	148	87	51	149	78	50
P.	177	84	59	176	81	61

From these figures we may draw the following conclusions:

a. When the syllable presented was exposed in the right place, this fact was realized by all the subjects in the great majority of cases. M. localized rightly only about two-thirds of the *RS* syllables. His is the lowest percentage obtained by any subject. G. and W. rightly localized more than nine-tenths of these syllables.

b. For the *FS* syllables the percentage of right localizations is much smaller than for the *RS* syllables except in the cases of G. and P., in which it is only slightly smaller. The difference is most marked in the cases of M. and B.

c. For the *RS* syllables the percentage of right associates is smaller in the case of every subject than the percentage of right localizations. The difference is most marked in the cases of W. and B. and least marked in the cases of M. and G.

d. For the FS syllables also, the percentage of right associates is smaller than the percentage rightly localized except in the case of M., with whom the percentages of right associates and of right localizations are almost the same. The difference is again least marked in the case of G. and most marked in the case of W.

e. Since the percentages of right localizations are much larger for the *RS* syllables than for the *FS* syllables, whereas the percentages of right associates differ little, there is much greater difference between the percentages of right localizations and right associates in the case of the *RS* syllables.

We may summarize these conclusions in the following statement: The subjects were in general much more likely to realize that an *FS* syllable was exposed in the wrong place than they were to recall the syllable paired with it and they were very much more likely to realize than an *RS* syllable was shown in the right place than they were to recall the other member of the pair.

In regard to individual subjects, it is important to note these two points: First, G. and W., who in the data given in Table I show least disturbance as a result of wrong-place exposure are the subjects who actually localized the largest percentages of syllables. From this we may infer that these two subjects remembered the place of the syllable exposed so clearly that wrong-place exposure had no confusing effect. The prowess of G. and W. in localization must not be attributed entirely to superiority in visualization. G. and W. were the two subjects who, in the test-procedure, were required to give the syllable preceding (not the syllable following) the one exposed. This harder task was imposed upon these two subjects expressly for the purpose of fostering attention to the spatial position of the syllables. Second, M., who in the data of Table I shows the most unmistakable evidence of disturbance by wrong-place exposure, is the subject who localized the smallest percentage of *RS* syllables and almost the smallest percentage of *FS* syllables and is the only subject who actually obtained a larger percentage of right associates than of right localizations for either the *RS* or *FS* syllables. From this we may infer that M.'s place associations were relatively weak, and that, in the case of the *FS* syllables, they were often blocked by the wrong-place exposure. From this comparison of G. and W. and M., it would appear that disturbance by wrong-place exposure was a mark of weak rather than of strong place associations.

III. *Was right localization actually in the case of individual syllables a concomitant of right association, wrong localization of wrong association and failure to localize of failure of association?*

This question must be answered (*a*) by comparing the cases of right localization, wrong localization and no localization as regards right associates, wrong associates and zero cases and (*b*) by comparing the cases of right and wrong association and the zero cases as regards right localization, wrong localization and failure to localize.

a. The data for comparing the cases of right localization, of wrong localization, and of no localization as regards right associates, wrong associates and zero cases are given in Table II. In this table the words *Indefinite Localization* at the heads of the 5th and 11th columns mean that, in the numbers of cases below, the subjects asserted, rightly or wrongly, that the syllable presented was shown in the wrong place but could give no more definite localization. The cases which are headed *Right Localization* and *Wrong Localization* are all cases in which the subject asserted that the syllable had stood in some particular place, perhaps the third or the seventh. The figures in this table are to be read vertically. The third column may be translated into words as follows: The subject M. rightly localized 316 syllables (out of 552 *RS* syllables and *FS* syllables taken together). Of these, 78 per cent called up right associates, 7 per cent wrong associates, and 9 per cent no associates at all. The remaining 6 per cent (not included in the table) called up partly right associates.[9] The subject G. localized correctly 782 syllables. Of these, 75 per cent were followed by right associates, 4 per cent

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[9] Any apparent discrepancies between the figures of Tables I and II are due to the rounding of the percentages into whole numbers.

TABLE II

To Show the Correlation between Right Localization and Right Association

Subjects	*Associates*	*Localization*				*Subjects*	*Associates*	*Localization*			
		Right	*Wrong*	*Indefinite*	*None*			*Right*	*Wrong*	*Indefinite*	*None*
1	2	3	4	5	6	7	8	9	10	11	12
M.	**Total**	**316**	**48**	**58**	**127**	D.	Total	**244**	**67**	**6**	**7**
	Right	78%	27%	21%	6%		Right	54%	10%	17%	0%
	Wrong	7	46	24	17		Wrong	15	40	0	14
	Missing	9	23	50	78		Missing	25	43	67	86
G.	**Total**	**782**	**26**	**0**	**21**	H.	Total	**245**	**27**	**2**	**23**
	Right	75%	31%	—%	10%		Right	60%	4%	0%	0%
	Wrong	4	19	—	0		Wrong	17	26	0	4
	Missing	18	46	—	90		Missing	28	67	50	96
W.	**Total**	**477**	**33**	**0**	**18**	P.	Total	**302**	**23**	**4**	**11**
	Right	46%	0%	—%	0%		Right	70%	4%	0%	0%
	Wrong	6	24	—	0		Wrong	4	48	0	0
	Missing	45	75	—	100		Missing	21	48	100	100
B.	**Total**	**192**	**98**	**10**	**31**						
	Right	38%	26%	0%	3%						
	Wrong	28	35	40	32						
	Missing	26	35	40	61						

by wrong associates and 18 per cent by no associates at all. And so on. This table shows the following facts:

1. *Right associates.* (*a*) Of the *RL* (rightly localized) syllables more than 50 per cent called up right associates in the cases of every subject except W. and B. (*b*) Of the *FL* (wrongly localized) syllables not more than 31 per cent called up right associates in the case of any subject. (*c*) Of the indefinitely localized syllables not more than 21 per cent called up right associates in the case of any subject. (*d*) Of the *NL* (not localized) syllables not more than 10 per cent called up right associates in the case of any subject.

2. *Wrong Associates.* (*a*) Of the *RL* syllables not more than 17 per cent called up wrong associates except in the case of B., who was peculiarly prone to name wrong syllables. (*b*) Of the *FL* syllables at least 40 per cent called up wrong associates in the cases of M., D., and P. G., W., and H. localized wrongly only a very few syllables and of these the percentage which called up wrong associates was also small. With B. the naming of wrong associates seems not to have hinged upon wrong localization. P., who localized quite as well as H., seems to have been led astray by wrong localization when it did occur. (*c*) Of the syllables indefinitely localized, none called up wrong associates except in the cases of M. and B., in which the percentages are 24 per cent and 40 per cent, respectively. (*d*) Of the *NL* syllables not more than 17 per cent called up wrong associates in the case of any subject except B., the hit-or-miss namer of syllables.

3. *Zero Cases.* (*a*) Of the *RL* syllables not more than 28 per cent were followed by negative reactions except in the case of W., who was as prone to say "Don't know" as B. was to name wrong syllables. (*b*) Of the *FL* syllables at least 46 per cent were followed by negative reactions except in the cases of M., B., and D., who, as already noted, were much more prone to wrong reactions than the other four subjects. (*c*) Of the syllables indefinitely localized, at least half were followed by negative reactions except in the case of B. (G. and W. never localized syllables indefinitely). (*d*) Of the *NL* syllables at least 78 per

cent were followed by negative reactions except in the case of B. who has 61 per cent. With P. and W. the percentage is 100.

These conclusions may be summarized by saying, first, that there is a correlation between right association and right localization and between failure of association and failure to localize but, second, that the *FL* syllables and the syllables indefinitely localized were likely to call up wrong associates or no associates according to the tendency of the individual subject to name wrong syllables or to say "Don't know."

b. We shall attempt to compare without the use of a table the cases of right, wrong, and no association as regards right, wrong, indefinite and failing localizations. The zero cases included in the discussion are only those in which the syllable presented was declared by the subject to be familiar. Unfamiliar syllables, of course, could not be localized. The results of B. are excluded because this subject seemed unable to pronounce upon the familiarity of the syllables, so that her zero cases are not comparable, as regards localization, with those of the other subjects.

1. *RS Syllables, Right Localization* (*RL*). (*a*) *RS* syllables followed by ***right associates*** were almost invariably localized by every subject. The lowest percentage obtained is M.'s 95 per cent. We have already remarked that M.'s place associations were relatively weak. (*b*) Of the *RS* syllables which had ***wrong associates*** at least 71 per cent were rightly localized except by M., whose percentage is 49. (*c*) Of familiar *RS* syllables which called up ***no associates*** at least 63 per cent were rightly localized by all the subjects and at least 83 per cent by all the subjects except M.

2. *RS Syllables, Wrong Localization* (*FL*)—definite and indefinite. (By ***indefinite wrong localization*** is here meant that the subject asserted that the *RS* syllable was shown in the wrong place but could not assign to it a particular place.) (*a*) *RS* syllables followed by ***right associates*** were almost never wrongly localized. The percentages for M. and D. are 1 per cent; for G., 0.3 per cent; and for the other subjects 0 per cent. (*b*) *RS*

syllables followed by ***wrong associates*** were wrongly localized in a considerable percentage of cases although even here the percentage of *FL* syllables is never large as compared with the percentage of *RL* syllables. G.'s percentage is only 7. The percentages of the other subjects range from M.'s 16 per cent to P.'s 29 per cent. The fact that P. has the highest percentage should be noted, as we have already seen that P., who has relatively few wrong localizations, was led astray by them when they occurred. (*c*) Familiar *RS* syllables followed by ***no associates*** were not often wrongly localized. The highest percentage of *FL* cases obtained by any subject is 17.

3. *RS Syllables, No Localizations* (*NL*). (*a*) *RS* syllables followed by ***right associates*** were practically always localized, at least indefinitely. M. has 3 per cent and G. 1 per cent of cases in which not even the indefinite localization of "right place" or "wrong place" was given. No other subject has any such cases. (*b*) *RS* syllables followed by ***wrong associates*** were always localized except by M. and H., who have 30 per cent and 7 per cent of *NL* cases, respectively. (*c*) Familiar *RS* syllables followed by ***no associates*** were usually localized though M. has 31 per cent of *NL* cases. No other subject has more than 6 per cent.

These statements in regard to the *RS* syllables may be summarized as follows: *RS* syllables were in general known to be exposed in the right places. Even when the *RS* syllables were followed by wrong associates or by no associates, they were still in general known to be *RS* syllables by all the subjects except M., whose place associations have been proved weak by other data. Nevertheless, the percentages of right localizations are considerably higher for the cases of right associates than for those of wrong associates or no associates.

4. *FS Syllables, RL.* (*a*) *FS* syllables followed by ***right associates*** were localized in a large majority of cases. M.'s percentage is only 80 and D.'s only 88. The percentage of no other subject falls below 97. The *RL* percentages for the *FS* syllables are naturally somewhat lower than the *RL* percentages for the

RS syllables, for the right localization of *FS* syllables was naturally the more difficult task. In order to localize an *RS* syllable correctly, the subject had only to feel that the syllable was shown in a familiar place, whereas, in order to localize an *FS* syllable correctly, he had not only to feel that it was shown in an unfamiliar place but also to name some one other particular place out of five or eight possible places. (*b*) *FS* syllables followed by ***wrong associates*** show a marked fall in the *RL* cases as compared with *FS* syllables followed by right associates. M. has only 7 per cent, P. has 30 per cent, D. 40 per cent, H. 64 per cent, W. 78 per cent, and G. 82 per cent. The disturbance of M.'s place associations by wrong exposure nowhere appears more clearly than here. (*c*) Familiar *FS* syllables followed by ***no associates*** also show a wide diversity in the *RL* cases for the different subjects. The percentages are: M., 19 per cent; D., 57 per cent; P., 69 per cent; H., 74 per cent; W., 77 per cent; and G., 81 per cent. It is clear that in the case of every subject except G. and W. the percentages are higher than the percentages for the syllables followed by wrong associates. Evidently failures to localize correctly were more frequent in the cases of wrong associates than in the cases of no associates.

5. *FS Syllables with Indefinite Right Localization.* "Indefinite right" localization of *FS* syllables means that the subject detected the wrong exposure without being able to assign the syllable to a definite place. (*a*) *FS* syllables followed by ***right associates*** were seldom thus indefinitely localized. M. has 10 per cent of these indefinite right localizations and H. 2 per cent. No other subject has any. (*b*) Of the *FS* syllables followed by ***wrong associates*** 33 per cent were given indefinite right localization by M. None were thus localized by the other subjects. (*c*) Of the familiar *FS* syllables followed by ***no associates*** 31 per cent were given indefinite right localization by M., 7 per cent by D., 6 by P. and 2 by H., but none by the other subjects. The number of indefinite right localizations made by M. is one of the clearest evidences of the weakness of his place associations.

6. *FS Syllables, FL.* In the case of *FS* syllables, wrong localization was necessarily definite as the reader will see with a

moment's reflection. (*a*) *FS* syllables followed by ***right associates*** were seldom wrongly localized. M. has only 9 per cent and no other subject has more than 8 per cent of such cases. (*b*) For the *FS* syllables followed by ***wrong associates*** the percentages are as follows: G., 19 per cent; W., 22 per cent; H., 36 per cent; M., 38 per cent; D., 58 per cent, and P., 70 per cent. (*c*) Of the familiar *FS* syllables followed by ***no associates*** not nearly so many were wrongly localized. The percentages are these: G., 8 per cent; W., 14 per cent; P., 14 per cent; M., 19 per cent; H., 21 per cent; and D., 28 per cent. A comparison of the last two sets of percentages again shows that wrong localization is much more closely bound up with wrong association than with failure of association.

7. *FS Syllables, NL.* (*a*) All the *FS* syllables followed by ***right associates*** were localized, definitely or indefinitely, by all the subjects except M., who has 2 percent of entire failures to localize. (*b*) All the *FS* syllables followed by ***wrong associates*** were also localized, at least indefinitely, by all the subjects except M. and D., who have 23 per cent and 3 per cent, respectively, of failures to localize. (*d*) A certain number of the familiar *FS* syllables followed by ***no associates*** failed of localization in the case of every subject. The percentages are as follows: H., 2 per cent; P., 3 per cent; D., 7 per cent; W., 8 per cent; G., 10 per cent; and M., 31 per cent. A comparison of these last two sets of percentages shows that entire failure to localize is more closely bound up with failure of association than with wrong association.

These detailed statements in regard to the *FS syllables* may be summarized by saying that a fairly clear correlation appears between right localization and right association, wrong localization and wrong association, and failure to localize and failure of association.

It is evident from the figures given in Table II and from the facts stated in the last few paragraphs that right localization and right association, wrong localization and wrong association, failure to localize and failure of association were, in these experiments, roughly correlated with one another. Nevertheless, as we said in our Introduction, a correlation between right localization and right association does not prove that place associations are highly serviceable as links in the recall of one syllable by another. The results which we have just considered show that the subjects tended to remember both the place of a syllable and its associate or to forget both, but this fact may mean simply that the syllable-sequence and the spatial setting were learned as inseparable parts of one content and not that the place association reinforced the syllable association.[10] Only the introspective testimony of the subjects can directly prove the reinforcement of one association by the other. Before entering upon the introspective data, however, we shall present one more set of numerical data, for these have an indirect bearing upon the exact relationship of right localization and right association.

IV. *Was right localization a concomitant of the feeling that the syllable presented was familiar and ought to evoke an associate?*

If this question be answered in the affirmative, one can easily see that right localization might indirectly contribute to right association by making the subject more strenuous in the attempt to recall the associated syllable even in cases in which the place association did not actually mediate the syllable association. Only in cases in which no associate could be given (zero cases) were the subjects questioned in regard to the familiarity or unfamiliarity of the syllable presented. Syllables which evoked definite reactions were, of course, assumed to be familiar.

a. The data in regard to the familiarity and unfamiliarity of the *RS* syllables which were followed by no associates and in regard to the localization of such of these syllables as were said or assumed to be familiar are presented in the following scheme:

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[10] If there be any relation of dependence between right association and right localization, then the former must depend on the latter much more often than the latter upon the former, since right localization is much more common than right association.

Subject	*Zero Cases*	*RS Syllables*				
		Syllables Familiar				*Syllables Unfamiliar*
	No.	*No.*	*% RL*	*% FL*	*% NL*	*No.*
M.	78	35	63	3	31	34
G.	84	81	85	6	6	1
W.	131	111	92	5	3	8
H.	53	39	90	8	3	14
P.	51	30	93	7	0	13

The results of D. are excluded from this scheme as well as those of B. because in the case of D. the experimenters were remiss in asking whether or not the syllable was familiar. The column *FL* covers cases of both definite and indefinite wrong localization. In the cases of nine *RS* syllables M. was unable to pronounce upon the familiarity. No such uncertainties occurred with the other subjects. In a few cases, however, with all the subjects, the question in regard to familiarity was omitted. Less frequently the question in regard to the place of familiar syllables was omitted. These cases, which have not been included in the scheme, account for the fact that the figures for the familiar and unfamiliar syllables do not always add to the total numbers of zero cases, and for the fact that the percentages under the heading *Syllables Familiar* do not always add to 100.

The scheme shows these facts: First, familiar *RS* syllables were rightly localized in a large percentage of cases by all the subjects except M. Second, M. has a very considerable percentage of cases in which familiar *RS* syllables could not be localized, and, indeed, all the other subjects except P. have a few such cases. Evidently, then, definite localization in the case of *RS* syllables was by no means essential to their familiarity.

b. The facts in regard to the familiarity and unfamiliarity of the *FS* syllables which were followed by no associates and in regard to the localization of the syllables which were said to be familiar are shown in this second scheme:

Subject	*Zero Cases*	*FS Syllables*				
		Syllables Familiar				*Syllables Unfamiliar*
	No.	*No.*	*% RL*	*% FL*	*% NL*	*No.*
M.	92	32	19	19	63	33
G.	94	88	81	8	10	4
W.	131	123	77	14	8	5
H.	54	34	74	21	6	20
P.	52	36	69	14	8	16

The column *NL* covers cases of both entire failure to localize and of indefinite localization. In the cases of M., H., and P., the percentage is about evenly divided between the two classes of cases. G. and W. have no indefinite localizations. The cases covered by the column headed *FL* are all cases of definite wrong localization.

This scheme shows, first, that the large majority of the familiar *FS* syllables were also rightly localized by all the subjects except M. and that, except by M., a considerable proportion of the residue of cases were definitely, though not correctly, localized. The scheme shows, second, that in M.'s case, a very large number of familiar *FS* syllables aroused no place association and that the percentage of these cases is by no means negligible in the case of the other subjects, particularly of G. Here again localization appears by no means essential to familiarity.[11]

If the scheme for the *FS* syllables is compared with the scheme for the *RS* syllables, it is clear that about as large a proportion of the *FS* syllables as of the *RS* syllables were familiar to every subject except H. In fact, a larger percentage of the *FS* syllables were familiar to W. This fact seems to show that wrong exposure did not in itself greatly tend toward making the syllable unfamiliar.

On the whole, then, we may conclude, first, that right localization did not, through any connection with the feeling of familiarity, play a very important rôle in recall; and, second, that disturbance of syllable associations produced by wrong exposure was not due to the fact that the wrong exposure made the syllables unfamiliar.

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[11] From the fact that our subjects pronounced familiar many syllables which they could not localize and for which they could name no syllable associate, it cannot be inferred that no associated images entered into their consciousness of the familiarity of the syllable presented. A conflict of several ideas of place would be enough to prevent a cautious subject from assigning a definite place to a syllable and yet the very presence of such ideas would prevent the consciousness of familiarity from being imageless.

In using the word *feeling* for the familiarity-consciousness, the writers imply the opinion that this consciousness is at least faintly affective.

Introspective Data

In this section we shall attempt to bring into connection with the numerical data the introspective testimony of the subjects in regard to the character of the imagery in which the syllables were memorized and the intentional use of spatial associations. Only the introspective testimony of the subjects on these points can show definitely whether right localization was a factor in producing right association or was simply bound up with right association as an integral part of the same memory content. We shall also note incidentally the testimony of the subjects to the use of auxiliary associations. In comparing subject with subject, the reader must remember that M., G., and W. learned series of eighteen members whereas the other subjects learned series of only twelve members, that G. and W. were required to give the syllable preceding instead of the syllable succeeding the one presented, that M. and G. had had vastly more practice, and that W. had (during the experiments) considerably more practice, in memorizing than the other subjects. M. is, for obvious reasons, the most important subject but for purposes of comparison it seems best to discuss him last. The other subjects will now be considered one by one.

G. is the subject who has by far the highest percentage of right associates and who ranks with W. in having a much higher percentage of right localizations than the other subjects. Little or no disturbance by wrong exposure appears in the results of G. although with G., as with other subjects, there is a rough correlation between wrong or failing localization and wrong or failing association. G.'s place associations appear to have been too strong to be dislodged by wrong exposure.[12]

G. memorized in terms both of visual and of auditory-kinaesthetic images. Her visual images of syllables are never verbal-visual images of the usual sort but are blotches of color, often variegated. (This subject has colored hearing in a marked degree but all her visual images are blurred in outline, so that she almost never visualizes a word or even a complicated letter entire.) In these experiments she saw each blotch of color in a sort of dark blurred frame, which was probably a reminiscence of the margin of black metal surrounding the syllable when exposed upon the tablet. In recalling the syllables, the visual image was the first to appear but was closely followed by the auditory-kinaesthetic image or by the consciousness of actually speaking the word. When the subject was not sure of the syllables, she often had an interplay of auditory images and more rarely of color images.

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[12] G.'s imagery and methods of memorizing have been very fully described in other places. See *Memorizing Various Materials by the Reconstruction Method,* Psych. Review, Whole Number 43, pp. 105 f. and pp. 184-185. *Cf.* also pp. 122 f. and 179 f. of these studies.

The subject consciously availed herself of the unusually good opportunity to form spatial associations but at first the arrangement of the syllables in three rows of six syllables each interfered in a very confusing fashion with her long established habit of grouping the syllables in fours and of visualizing the groups (in series not exceeding thirty-six members) in a single horizontal row. This difficulty was overcome as the experiments proceeded. The subject had long been accustomed, in memorizing series of syllables, either to project the syllables into definite spatial positions in the field of mental vision or to project them upon portions of external space as, for example, upon different parts of a table. The squares of the exposure-tablet furnished a particularly convenient system of compartments for the syllables, even although at first the subject felt as if she would willingly dispense with the exposure-tablet in favor of her own visualizing arrangements.

In impressing the syllables upon herself, G. looked very attentively at the squares of the tablet and also sometimes made use (in internal speech) of such words as "seventeenth" or "next to last." If she thought of the series at a moment when she was not actually looking at the tablet she visualized the blotches of color as emerging, one or two at a time, in a pattern corresponding to the squares of the tablet. It is evident, therefore, that she intentionally "worked" her place associations in memorizing the series. In the test-procedure, however, when she was actually looking at the tablet, she rarely projected the visual (color) image of a syllable upon it. The synaesthetic image of the reaction-syllable seemed to form behind her eyes. When the stimulus-syllable was presented in the wrong place, the subject was often distinctly conscious of having glanced at its proper place before the syllable paired with it came to mind but often the reaction-syllable emerged with or before the localization of the stimulus-syllable. Apart from verbal images of syllables, internal speech was not very prominent in the recall process.

This subject in these experiments made much, though by no means constant, use of artificial associations, frequently making the syllables into words and then linking the words through their meaning, represented in sketchy concrete-visual terms. Thus, *e.g.*, she connected "bus" and "shipe" as "omnibus" and "ship"—both traveling conveyances. These auxiliary associates were sometimes recalled more readily than the proper syllable. Thus, *e.g.*, the subject connected "chude, quish" by thinking of "quish" as something to be chewed but, when "quish" was presented, she could only remember that she had thought of it as something to eat. These devices seem rarely to have led to the naming of wrong syllables for, in the case of this subject, the number of wrong cases was exceedingly small. G. was probably better able to make, and less able to inhibit, mnemonic devices than any of the other subjects, since she had had long practice in memorizing at slower rates of repetition and had been tempted by the long intervals to fall back on auxiliary associations whenever the series was hard to memorize.

W. is the subject who had the large number of zero cases and the very short reaction times and who ranks with G. in her large number of right localizations. W. is preëminently a visualizer but certainly has at the date of writing, and probably had during the experiments, a certain amount of auditory-kinaesthetic imagery. Her visual-verbal imagery is of the usual type and sharply clear.

In memorizing, W. did not deliberately impress upon herself the spatial positions of the various syllables but learned position as if it were "part and parcel" of the syllable itself. In recalling a syllable, she saw it "tacked into its place on the tablet." In trying to remember a syllable, she was accustomed to run over parts of the series in mental vision. Thus W. differs from G. in not making deliberate use of place associations to reinforce syllable associations. It would not have been possible for W. to learn a series from the tablet without having the positions of the sequences quite as firmly impressed as the sequences themselves. Thus with W. right localization seems not to have mediated right association and yet to have been its necessary accompaniment. With W., however, more than with any other subject, wrong localization led directly to the naming of a particular wrong syllable. If, for example, W. wrongly supposed that the syllable presented was the 8th, she would be pretty sure to name the 7th syllable as its associate. This tendency, which plainly shows the strength of W.'s place associations, was not marked with any other subject. In the case of M., who, except perhaps for B., was the poorest localizer among all the subjects, mistakes of this class constituted less than ten per cent. of the total number of wrong reactions. M.'s wrong syllables were usually syllables which had some resemblance to those which he should have named or else were syllables which, for some reason, had attracted his special attention. With G., who like W. could localize almost every syllable shown, wrong syllables were nearly always those which had caught her attention, either by their "color" or by their liquid consonants or by their meaning. It is greatly to be regretted that it is impossible to give exact statistics for any subject except M. on this important point. The original records for the other subjects perished in the Wellesley fire.

W. used mnemonic devices to some slight extent and these associations were of the same type as G.'s.

A word remains to be said in regard to the shortness of W.'s reaction times, to which her small percentage of right associates was undoubtedly due in part. (It will be remembered, however, that W.'s task was harder than that of any other untrained subject.) After the experiments were completed W. explained her hastiness as partly due to "fright" and partly to a habit of quickly "giving up" anything which she could not readily recall. She is one of the persons who exhibit celerity in the recall of any material which still remains at command and who have learned by experience that images which do not come promptly often fail to come even after strenuous efforts to summon them. The subject was often able, however, to give the proper reaction after releasing the lip-key and was thus made to feel that she had not taken time enough to "think." She attributed her nervousness, in part, to the fear that she would not release the lip-key properly.

B. was the subject who had the smallest percentage of right and the largest percentage of wrong associates. B. also had very short reaction times and relatively small percentages of right localizations. She was obviously the poorest memorizer of all the subjects and also gave less satisfactory introspection than any of the others.

The imagery of which she made actual use was mainly "auditory." She also had visual images of the syllables but these images were composed of vague "jumbles" of letters. She had great difficulty in pronouncing the syllables so that the mere reading of them engrossed her attention and left little time for the formation of either place or of other auxiliary associations. Her difficulty in pronouncing the syllables, moreover, made even her auditory images shifting and vague. It is impossible to glean from the data at hand in regard to B. whether or not she ever deliberately made use of place associations.

D. is one of the subjects whose associations seem to have been somewhat disturbed by wrong exposure. Her percentage of right localizations is not particularly large. Her imagery was "auditory." The only visual images which appear to have figured in it were images of the first elements of the syllables. She did not report any intentional use of place associations. She made free use of mnemonic devices, giving meaning to the syllables by virtue of their similarity to English or to French words. In attempting to recall a syllable she would either repeat in internal speech the one presented or try to recall the mnemonic device which she had used for connecting it with its mate.

H., again, is one of the subjects whose associations appear to have been disturbed by wrong exposure. Her percentage of right localizations is large, though not as large as those of W.

and G. H.'s imagery was almost, if not quite, exclusively visual. She herself expressly disclaimed auditory and kinaesthetic imagery. She did not, however, like W., visualize the tablet when thinking of the series or of the place of a particular syllable but seems, like G., simply to have visualized the syllables arranged in rows similar to those upon the tablet. Like G., she made conscious use of place associations both in learning the series and in attempting to recall syllables.

H. made less use of really artificial associations than did any other subject, except perhaps M., but paid much attention to the constituent elements of the syllables, particularly to the qualities of the vowels, comparing them with one another from syllable to syllable.

P. is the subject who was able to recall more right associates in the case of wrong exposure than in the case of right exposure. Her percentage of right localisations is large but no larger than that of H.

P. also claimed imagery almost exclusively visual. Like W., she visualized the tablet distinctly and, when localizing the syllables, projected them into their places upon it.

Like H. and G., she made deliberate use of place associations both in learning and in recall. Like H., she carefully noted and compared the constituent elements of the syllables, especially the qualities of the vowels but she also made free use of artificial associations of miscellaneous sorts.

The subject M., who initiated the experiments, is the only subject with whom disturbance of associations by wrong-place exposure of the stimulus-syllables is very conspicuous. We have already noted strong evidence that his place associations were by no means stronger but, on the contrary, much weaker than those of most of the other subjects. On the other hand, in his total number of right associates, M. ranks third, coming after G. and P. only.

M.'s imagery was "vorwiegend visuell." In the process of recall, images of the reaction-syllables or parts of them were projected upon the squares of the tablet. M. read the series with a very marked intoning, not called for by the simple trochaic rhythm, and put a distinct caesura after the third and the sixth foot. This intoning undoubtedly tended to give a certain temporal (non-spatial) placing to the various syllables but it also was perhaps an indication of a striving to make poor auditory imagery more serviceable.

M., of course, paid special attention to the spatial setting of the syllables and tried to make all the use possible of place associations. In reading, he both inclined his head slightly and pointed with the index finger of his right hand to the different parts of the series in turn. The *importance* of the place associations thus formed is attested by the numerical results. The experimenter can explain their relatively weak and treacherous character only in the following way: M. had had much practice in memorizing syllables presented one at a time upon a revolving drum and had been accustomed to visualize them sharply by pairs. This habit may have interfered somewhat with the use of place-markers (the squares of the tablet) which were not paired off,[18] and also with the formation of a vaguer and more complex image of a larger part of the series. Certainly we cannot account for the weakness of M.'s place associations, as we can for the weakness of B.'s and of D.'s, by inferiority of visual imagery.

M. occasionally reported the out-cropping of an auxiliary association but his analysis of the syllables into their elements was close and unremitting.

The introspective data will now be summarized in combination with the numerical results.

Conclusions

I. *a.* The introspective testimony shows that four subjects made conscious use of associations of spatial position. These subjects were M., G., H., and P. Of these, M. and H. seem to have been appreciably disturbed by wrong exposure, whereas G. was just perceptibly disturbed and P. seems actually to have been helped. On the other hand, disturbance does appear in the case of D. who reports no conscious use of place associations. Thus, it is clear that disturbance by wrong exposure was not correlated with *conscious* use of associations of spatial position.

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[18] In the experiments of Jacobs (*op. cit.*, p. 51), M. found a drawback to the use of the external-localization scheme in the fact that the little black circles were not paired off.

b. Neither was disturbance by wrong exposure correlated with facility in making spatial associations, for the two best localizers, G. and W., show the least disturbance by wrong exposure, and the poorest localizer (among the subjects whose results need to be seriously considered), namely M., shows most disturbance.

II. *a.* Facility in making place associations seems to have been an asset, though not an unfailing asset, of eye-mindedness.

b. This facility did not involve an intentional use of such associations in recalling syllables presented to the eye. In the mind of W., the syllables and their settings seem to have been too closely fused to have any separate value in suggesting other syllables.

III. Definite localization did not seem to be essential to the consciousness that a syllable was familiar, nor can it be maintained that wrong exposure made the syllables seem unfamiliar and thus deterred the subjects from persistent attempts at recall. For by all the subjects, except one, nearly the same proportion of wrongly as of rightly exposed syllables were pronounced familiar.

IV. *a.* In the numerical results, the sought-for correlation between right *exposure* and right association and between wrong exposure and wrong or negative response is distinctly traceable.

b. A slight correlation also appears, within the results of the subjects taken individually, between right *localization* and right association. But if the subjects be compared with one another, it cannot be said that facility in the localization of the stimulus-syllables was coupled with facility in the recall of the syllables paired with them. One of the two best localizers (W.) is also one of the two subjects who had the smallest percentage of right associates.

V. Correct localization of the stimulus-syllables was vastly more frequent than correct recall of the syllable paired with it. Therefore, if any dependence at all is involved, right association must hinge upon right localization.

If we are to sum up the chief outcome of the experiments in a single sentence, we must say that *associations of spatial position played a clearly demonstrable rôle in recall with all the subjects except B. whose visual imagery was the poorest and (curiously enough) except W., who was the most inveterately eye-minded of them all.* This rôle may be one of help or—if place associations interfere with one another—one of hindrance. The interference may be entirely *subconscious—i.e.,* a mere matter of cortical processes without conscious correlates.

PART II

SPATIAL ASSOCIATIONS IN MEMORIZING

Method and Apparatus

The problem of the second part of our experiments has already been discussed (p. 49). In brief, it was to demonstrate any advantage which might exist in learning series of syllables from the exposure-tablet as compared with the revolving drum, which brought them singly into view behind a screen-slit. On the tablet, the syllables were exposed simultaneously and in conspicuous spatial relations to one another; on the drum, they were exposed successively and all in the same spot. The method of these experiments was precisely the same, *mutatis mutandis,* as the method used in the earlier experiments. Series were learned from the drum and from the tablet according to a cyclic program. The test-procedure for each series took place three minutes after the end of the last reading. The later test-procedure differed from the earlier in this one point, namely, that the stimulus-syllables were all shown—whether the series had been learned from the tablet or from the drum—in one particular place on the *tablet,*—the third square in the second horizontal row. After each reaction, the subject was asked to name the position—the fifth, the ninth, or what not—which the stimulus-syllable had occupied in the series.

It is necessary to lengthen this section only by giving some description of the revolving-drum apparatus. This was made by Spindler and Hoyer and is described in their catalogue under the title "Gedächtnisapparat, Eigenkonstruktion."[1] It was supplied with interchangeable metal drums of three different sizes. Each drum, when in position, rotated about the same horizontal axis by clockwork which was controlled by a falling weight. In front of the drum was a small screen containing a slit, 5.7 cm. wide by 3.8 cm. high. When this slit was uncovered (by withdrawing a small sliding screen), a single syllable was visible on the white paper fastened about the drum. The rotation of the drum was accomplished by means of a cog-wheel so that it moved in jerks, showing each syllable for a moment and then rapidly replacing it by another. The rate of rotation of the drum could be controlled either by changing the weight or by altering the adjustment of the vane. To both subjects the syllables were presented at the rate of one per second, so that the time occupied in reading the series was the same in the drum as in the tablet experiments. In those with the subject C., the middle-sized drum was used and this drum worked properly. In the experiments with G. (for whom twelve-syllable series were too easy), the largest drum had to be employed. This drum moved irregularly, because some of its cogs were not properly made, and this circumstance greatly annoyed the subject (who felt responsible for the behavior of the apparatus) and often seriously distracted her attention.

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[1] *Apparate für psychologische Untersuchungen,* p. 150. The apparatus is familiar in several American laboratories.

Numerical and Introspective Results

The numerical results are presented in Table III.

This table is modelled after Table I. (See pp. 62 and 63.) The only new feature is the fifth column, in which the letters *T* and *D* stand for *tablet* and *drum* respectively. The first line of the table may be translated as follows: The subject G., in memorizing, read from the tablet series of twenty-two nonsense syllables at first three times and afterwards twice each. In the test-procedure, the odd-number syllables were shown so that the subject was required to name the syllable succeeding (not that preceding) each stimulus-syllable. In these tablet experiments, the stimulus-syllables were 292 in number. Of these, 71 per cent called up right associates in an average time of 3640σ. And so on.

One or two explanatory remarks on procedure have been reserved for this place. G. was asked to name the syllable following rather than the syllable preceding the stimulus-syllable in order that her task might be the same as that of C., an unpracticed subject for whom the naming of the preceding syllable was

TABLE III

To Show the Results of Simultaneous Exposure upon the Tablet as Compared with Successive Exposure upon the Revolving Drum

Subject	*Series Length*	*Repetitions*	*Syllables Shown*	*Apparatus*	*No. of Stimulus Syls.*	*Right Associates*		*Partly Right Asso.*		*Wrong Associates*		*Zero Cases*	
						%	*Time*	%	*Time*	%	*Time*	%	*Time*
G.	22	3, 2	O.	T.	292	71	3640σ	2	6390σ	6	7150σ	21	8060σ
		3		D.	287	55	2980	3	4130	11	5500	32	7550
C.	12	3	O.	T.	234	47	2670	9	6180	18	6260	27	8310
		3		D.	228	45	3270	6	5350	22	6300	28	7130

supposed to be too hard. As G.'s task was thus made easier than it was in the earlier experiments, it was advisable to make a compensating increase in the length of the series. The length twenty-two was taken because this was the largest number of syllables which could conveniently be presented on the largest of the three drums. The two squares at the right end of the fourth horizontal row on the tablet were left vacant. The readings of the series on the tablet had to be reduced from three to two because with three readings the subject was getting far too many of her reactions right;—*i.e.*, was making only one class of cases, that of right associates.

The discussion of the numerical and of the introspective data will be blended and the results of the two subjects will now be considered one after the other, taking first the unpracticed subject, C.

C. (Josephine Nash Curtis) was an undergraduate student in a second full-year course in psychology. In this work she served both as experimenter and as subject. As a preliminary measure, she was drilled in the use of the apparatus by a series of practice experiments not reported here. Her results show a distinct advantage in learning from the tablet as compared with the drum. With the tablet, she has a slightly larger percentage of right associates with a considerably shorter reaction time (2670 as compared with 3270σ); and she also has a slightly smaller percentage of zero cases with a slightly longer time. She also has, with the tablet, a slightly smaller percentage of wrong associates although the wrong-reaction time is about the same as that with the drum. C. claimed that her imagery was "chiefly visual" although she admitted having "auditory" imagery also. She did not, in the drum experiments, visualize the tablet and project the series upon it after the fashion of inveterate visualizers. (*Cf.* the practice of G. as stated below and that of Jacobs's eye-minded subjects.) Nevertheless, she correctly stated the positions in the series of a considerable percentage of the drum syllables. Her percentages of right placings are given in the following scheme and for convenience of comparison G.'s percentages are included with them:

Subject	*Apparatus*	*Percentages of Right Placings for Stimulus-Syllables Followed by*		
		Right Associates	*Wrong Associates*	*No. Associates*
G.	Tablet	93	50	39
	Drum	88	42	23
C.	Tablet	97	86	65
	Drum	42	25	13

This scheme shows that, on the one hand, C. was by no means oblivious of the position of syllables in the drum series, but, on the other hand, that her placing of the drum syllables was very poor both in comparison with her localization of the tablet syllables and with G.'s placing of the drum syllables. C.'s attention to the place of the drum syllables was probably due chiefly to her being constantly questioned as to their places. But her conscious use of spatial associations in the tablet series is certain. She reported that in learning from the tablet the syllables "paired off naturally," whereas, in learning from the drum, a syllable had no more connection with the one following than with the one preceding it. This she reported in spite of the fact that she read the pairs of syllables from the drum in correct trochaic rhythm. She also said that, in the test-procedure with the tablet series, whenever she could not at once recall the proper syllable, she was accustomed to "try" the stimulus-syllable in different places on the tablet, and that when she "found the right place," the right associate would generally come to mind. With the "drum syllables," she said that "there was no such way of trying to remember" and so she "gave up sooner." C. made some use of auxiliary associations.

With G. the advantage of learning from the tablet appears very great indeed. In the tablet experiments, the percentage of right associates is much greater (71 as compared with 55) and the percentage of zero cases much smaller (21 as against 32). Moreover, she has, with the drum, 11 per cent. of wrong associates, a large number for her. Furthermore, her reaction times for all classes of cases are decidedly shorter with the drum, an unmistakable sign that with the drum a larger number of stimulus-syllables were devoid of any glimmering of associates. As a matter of fact, G.'s method of procedure in the two sets of experiments was not so very different. When learning from the drum, she intentionally visualized the spots of color representing the syllables in four horizontal lines in a pattern exactly resembling the tablet pattern. In other respects, her method in both sets of experiments was exactly the same as her method in the earlier experiments. (See p. 82.) Her placing of the drum syllables was *bona fide* spatial localization and (as the scheme on page 95 shows) it compares very favorably with her placing of the tablet syllables. In view of the similarity of G.'s method in the two sets of experiments, the enormous advantage of the tablet series as shown in Table III seems at first sight surprising. It is, however, all too easily explained. In the first place, the subject, in spite of much practice in memorizing, had never before learned syllables presented to the eye singly and, so to speak, "on the move." Under the best of circumstances, she would probably have felt a certain nervousness when first learning from the drum. But, in the second place, her eyesight, at the time this work was done, was very poor so that she had great difficulty in reading the syllables quickly enough from the drum, although they were written with India ink and very legibly. In the first and often in the second reading, her attention was wholly taken up with the bare deciphering of the syllables so that none was left for linking them in any fashion. In reading from the tablet, to be sure, she sometimes hesitated but, with the tablet, it was often possible to look back at a half-read syllable even while pronouncing another on the proper metronome-beat. In the third place, G. was frequently vexed by the momentary stopping of the drum, whose irregular behavior no one ever succeeded in entirely correcting. In view of these facts, it is clear that G.'s numerical results, though striking, are not very significant.[1]

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[1] As a matter of fact, in certain somewhat similar experiments which are now in progress, this subject is obtaining slightly better results with "internal" than with "external" localization. In these experiments, however, presentation is in both cases aural.

The figures which show the relative familiarity of the tablet and drum syllables in the experiments here reported appear to have been among the records which were burned.

Conclusion

These experiments, as far as they go, tend to show what was indicated by the numerical, and proved by the introspective, results of the earlier experiments, namely, that *associations of spatial position may be not merely a concomitant but also a really mediating factor in the recall of one nonsense syllable by another.* The argument based upon the later experiments runs as follows: *Syllable sequences are better recalled if the series are presented for memorizing in such a fashion as to foster the formation of place associations.* The main argument based upon the earlier experiments is this: *The recall of one syllable by another is blocked if measures are taken to make any place-and-syllable associations which may be formed interfere with one another.*

The results of these later experiments are exactly in line with the findings of Jacobs. The correspondence is the more significant on account of the differences of method. It will be remembered that Jacobs used aural presentation and provided his subjects merely with rows of round black spots upon which they were required mentally to localize the syllables. We, on the other hand, furnished the conditions of perceptual localization. The purport of all three series of experiments, those of Jacobs and our own two series, is the more convincing, because in none of them does the rôle played by place associations loom incredibly large.

Two Studies in Memorizing by Slow And by Rapid Repetition

I.

RATE OF REPETITION AND TENACITY OF IMPRESSION

By E. A. McC. Gamble

With the Assistance of Agnes G. Rockwell, Florence M. Kunkel, and Helen A. Forney

II.

THE RELATIVE AMOUNTS OF FATIGUE INVOLVED IN MEMORIZING BY SLOW AND BY RAPID REPETITION

By Josephine Nash Curtis

With the Assistance of Helen K. Goss and Ethel Caution-Davis

I.

RATE OF REPETITION AND TENACITY OF IMPRESSION

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I.

RATE OF REPETITION AND TENACITY OF IMPRESSION

Introduction

This paper and the paper which follows are both off-shoots of the writer's "Study in Memorizing Various Materials by the Reconstruction Method."[1] It is unnecessary here to say much of the rough but extended series of experiments made by this method, but it is necessary to call the reader's attention to their general nature and outstanding results, since the problems of the two papers here submitted will be better understood if their historical and logical connection with the earlier work be traced in some detail. This introduction, therefore, will contain (I) a very brief account of the reconstruction experiments, (II) an enumeration of the links which connect the reconstruction work with this present work, and (III) the formulation of the problem of this paper and of the next.

I. By the term *reconstruction method* is meant the procedure in which series of objects are presented to the subject who is afterwards required to arrange them in the order in which they were originally given. This performance may be repeated until the reconstruction is both accurate and unhesitating. In the writer's experiments, the material consisted of scents, of colors, and of nonsense syllables written upon small oblong cards. The results of these experiments are in two respects in marked contradiction to the results usually obtained by the method of complete memorizing, or *Erlernungsmethode,* the method of Ebbinghaus and of Müller and Schumann.[2] In the first place, practice tended to reduce the number of repetitions necessary for memorizing by the reconstruction method to the same number for longer and longer series, so that to the practiced learner the length of the series was of surprisingly small importance. In the second place, the number of repetitions required was remarkably small, even with untrained subjects. The number of repetitions necessary for a completely accurate and unhesitating reconstruction rarely exceeded four, even with beginners who were memorizing series of eighteen members, or with practiced learners who were memorizing series of thirty-one or of forty-one. These figures are in striking contrast with the numbers of repetitions, rarely falling below ten, which were necessary for memorizing series of twelve nonsense syllables in the experiments of Müller and Schumann and with the very similar results of other experimenters who have worked with the method of complete memorizing. One should especially recall in this connection the statement of Ebbinghaus: "Whereas I am able, almost without exception, to recite series of six nonsense syllables without mistake after a single presentation, I can recite series of twelve syllables (read rapidly) only after from fourteen to sixteen repetitions, series of sixteen only after thirty, and series of thirty-six only after fifty-five."[3]

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[1] *Wellesley College Studies in Psychology,* Psychological Review, Whole Number 43. Throughout this paper, this work will be referred to as *Memorising by the Reconstruction Method.*

[2] The nature of this method may be briefly indicated as follows: A series of words or syllables is repeated over and over again until it can once be recited without inaccuracy or hesitation. The first repetitions are made by the experimenter who presents the whole series to the subject. At the end

II. The connection between the reconstruction experiments (virtually finished in 1905) and the experiments here reported (which were begun in 1910) may be traced (*a*) through other experiments and (*b*) through a theory suggested by them.

a. The contrast just indicated between the results obtained by the reconstruction experiments and by the method of complete memorizing led the writer to make an experimental study of the reconstruction method itself.[4] This study included experiments with nonsense syllables by the method of complete memorizing

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of any repetition the subject may begin to recite, but as soon as he hesitates or makes a mistake, the rest of the series is presented to him. The method is more fully described on p. 111 below.

[3] *Grundzüge der Psychologie*, Zweite Aufgabe, p. 651. *Cf. Memorising by the Reconstruction Method*, pp. 76, 87-89 and 206.

[4] *Memorising by the Reconstruction Method*, Chapter VI.

and led, by numerical and introspective evidence, to the following conclusions: (1) The small number of repetitions necessary for memorizing series of any practicable length by the reconstruction method was due in large measure (a) to the fact that the subjects were allowed unlimited time for reconstruction and were thus enabled to work with emotional composure and (b) to the fact that the rate of presentation was very slow. The nonsense syllables and colors were presented at intervals of from three and a half to four seconds and the smells at intervals of five seconds. Thus, the rate at which the nonsense syllables were presented was, roughly speaking, only one tenth as fast as the rate used by Ebbinghaus in his classical experiments, and only about one-fifth as fast as the rates ordinarily employed in the method of complete memorizing. (2) Even in this method of complete memorizing itself, the number of necessary repetitions can be very greatly reduced by reducing the rate at which the series is repeated, although this saving of repetitions is ordinarily accomplished at the cost of some waste in the total learning time. The subject learns more in a single slow repetition than in a single rapid repetition but learns more in the rapid repetition in proportion to the time spent upon it.[5] (3) In the method of complete memorizing, also, reducing the rate at which the series is repeated greatly reduces the importance of series length. It would seem on introspective grounds that this fact is due to the lessening of the mutual interference of the associations, the crowding out of one part of the series from the learner's mind by another.[6] (4) Learning by slow repetition under the conditions of either the reconstruction method or the method of complete memorizing fosters the development of a technique in learning, which could not readily be acquired through learning by fast repetition, but which, once acquired, can be transferred to learning by rapid repetition.[7]

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[5] This result is entirely in agreement with the findings of other experimenters. See the references given on page 157 below.

[6] Ebbinghaus says (if translated): "Many persons can never, in a reasonable time, achieve a perfectly correct recitation of the longer series of nonsense syllables. Some parts are continually thrown into confusion by others. . . . The readings which follow the first readings of the series often seem to bring about only a slight increase in the subject's power to reproduce it. The mutual disturbance of the series members by one another, which is distinctly manifest to immediate consciousness, brings the process of learning to a standstill and only when the whole series has become somewhat more familiar through numerous readings, does a further increase in the number of retained elements take place." *Grundzüge*, p. 651.

b. The repetition-saving advantage of slow repetition is somewhat parallel to the repetition-saving advantage of distributed repetitions (*Verteilung der Wiederholungen*), an advantage which was demonstrated by Jost. This parallel led the writer to compound out of the doctrines of Professor G. E. Müller and his disciples, (1) a physiological theory of the repetition-saving advantage of slow repetition with (2) a complementary theory of the time-saving advantage of fast repetition. Such a physiological theory is, of course, purely speculative, whereas the tendency of slow repetition to foster the development of technique is a fact of clear introspection. But, however small the value of the writer's theory may be, it is necessary to mention it here because it led directly to the experiments reported in this paper and the next. The theory is set forth in full in the last pages of "Memorizing by the Reconstruction Method." Here it may be summarized in the following statements: (1) An association, in the physiological sense, consists of such a modification of the nerve-path connecting two cortical areas that excitation tends ever afterward to run from one to the other, or, to put the matter still more vaguely, of such a modification of the cortex that the excitory process of one idea tends ever afterward to involve that of the other. The formation of such a modification,—say, by the attentive repetition of two nonsense syllables—requires cortical energy, whatever the nature of this energy may be. If the modification is at all lasting, some process of consolidation or "setting" must take place and this process also requires cortical energy. The amount of nervous energy available in the cortex at any one time is limited. Therefore, when a number of associations, which we may symbolize by letters, are formed in quick succession, the initiation, say, of *e* - *f* draws energy away from the consolidation of *d* - *e*. Thus, *d* - *e* will be less firmly stamped the more quickly, at each repetition of the series, its impression is followed by the impression of *e* - *f*, and in so far as *d* - *e* is being consolidated, it will weaken the impression of *e* - *f*. Thus, a single rapid repetition of a series accomplishes little. Slow repetition has a physiological advantage. *Only multiplication of repetitions can make up for rapidity of repetition.* (2) Rapid repetition greatly increases the perseverative tendencies of the series members. Therefore, a *short* series, if rapidly repeated can be learned for purposes of *prompt recitation* in a relatively short time, since in the case of a short series, the perseverative tendencies of the members may more than make up for the comparative weakness of the associations between them. But the number of words or syllables which tend to perseverate at any one time is very limited. Moreover, rapid repetition tends to increase not only the perseverative tendencies but also the mutual interference of the members—that interference which is so clearly manifest to introspection and which is doubtless the psychic index to the draughting of cortical energy in too many directions at once. Therefore, *long* series cannot be learned by rapid repetition within a "reasonable time" unless the learner has acquired a most unusual technique. (This statement holds, of course, only for the learning of meaningless material.) Moreover, perseverative tendencies,—as (or if) manifested in the "mental echo" of the series—fall away rapidly with lapse of time, running down noticeably in the first thirty seconds and becoming after three minutes negligible as an aid in repeating even a twelve-syllable series. Hence, if a series is to be recited largely in virtue of the perseveration of its members, it must be recited at once and rapidly.

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[7] G., the present writer and the principal subject in all these experiments, was able at maximum practice, to learn, by the method of complete memorizing, series of eighty-one syllables in one hour when the syllables were presented at intervals of five seconds, and in three quarters of an hour when they were presented at intervals of one second. The time required for learning syllable series of the same length by the reconstruction method was one hour and a half, but this time included the considerable periods necessary for recording the results of each trial.

At the time this theory was propounded, the writer held a view of recall, which was afterwards more clearly formulated by

Titchener, who indeed is far from espousing it but sets it forth only to reject it. According to this view three different tendencies may come into play when the word or syllable *e* has been strongly associated with the word or syllable *f* and soon afterward recurs: (1) The impressional tendency of *f*, that is, its readiness to emerge (as an image), "the distance below the conscious limen at which its excitory process is now going on"; (2) the associative tendency, which indexes the strength of the connection between the excitory processes of *e* and *f*; and (3) the perseverative tendency of *f*, which is "a sort of rhythm impressed upon the impressional tendency," such that *f* may "now and again emerge without the aid of the associative tendency." It is this rhythmical, non-associative recurrence which Titchener rejects as unproved.[8] In the theory of the present writer, impressional and perseverative tendencies were not distinguished from each other, but the rhythmical character of something which might well have been called the "impressional tendency" was suggested. In most cases in which the term *perseverative tendency* is used in this paper, *impressional tendency* might be substituted. The writer did indeed (and does still faintly) believe that a *recent, vivid* and *oft-repeated* percept might recur as an image without the aid of association, but has never supposed that a whole series of syllables could be recited *in order* in virtue of perseveration alone. For if equal attention were given to all members of the series, the perseverative tendencies of the last repeated would be the strongest, so that if the series emerged in virtue of perseveration it would be likely to emerge in reverse order—"wrong-end-to." But in the rapid recitation of a much and quickly repeated series, one is conscious of no rearrangement except in so far as one is conscious of the mental echo of the last few syllables in a sort of polysyllabic nonsense word and is conscious of putting this aside in order to "begin at the beginning." In beginning the series and in reciting it in proper order, perseveration, if operative, must simply facilitate association. One has different feelings or "attitudes" (*Bewusstseinslagen*) when one is reciting a series rapidly repeated many times and when one is reciting a series slowly repeated two or three times, even when one does not hesitate in either instance. In the one case, one feels as if one were speaking automatically; in the other, as if recitation really involved "voluntary" recall. Do these different feelings, however they may be analyzed in organic and kinaesthetic terms, indicate a difference of kind in the nervous conditions of recall? The question is surely worth asking and trying to answer.[9]

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[8] *Cf.* Titchener, *Text-Book of Psychology*, pp. 400-401.

III. The problem of this paper and that of the next are questions which test the theory just outlined,—questions whose answers must buttress or in some degree undermine the theory. The questions are these:

a. If learning by fast repetition involves a severer demand upon cortical energy than learning by slow repetition, then *learning by fast repetition should be the more fatiguing to the subject. Is this the case?* This is the problem of the second paper.

b. If the reason that fast repetition saves time is that a series can, in virtue of the perseveration tendencies of its members, be recited before the associations between the members are firmly stamped, then series learned by fast repetition should not be so well remembered as series learned by slow repetition, series which must be recited wholly in virtue of association and not partly by the aid of perseveration. *Are series learned by fast repetition as well remembered as series learned by slow repetition?* This question constitutes the primary problem of this present paper. A secondary interest lies in securing evidence for a consolidation process in the case of slow repetition. The experimental conditions and data may now be presented.

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[9] The *locus classicus* for the doctrine of perseveration in normal psychology is Müller and Pilzecker, *Beiträge zur Lehre vom Gedächtniss,* Zeitschrift f. Psych. und Physiol. der Sinnesorgane, Ergänzungsband 1 (1900), pp. 58-78. According to this passage, the term *Perseverationstendenz* means the tendency of a recent, vivid and repeated experience to return to consciousness spontaneously (*frei*), *i.e.,* not in virtue of an associative connection. This is the meaning attached to the term *perseverative tendency* by the present writer, except that she would prefer to say, "not *or not wholly* in virtue of association." For a destructive study of the doctrine of perseveration as thus construed see Foster, *On the Perseverative Tendency,* American Journal of Psychology, 25, pp. 393-426. For the theory of consolidation processes, see Müller and Pilzecker, *op. cit.,* pp. 195-198. See also Müller's paper on *Wiedererkennung und rückwirkende Hemmung,* with the discussion following, in the Bericht über den V. Kongress für experimentelle Psychologie (1912), pp. 216 f. Jost's work is found in the Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 14 (1897), pp. 436, f. His title is *Assoziationsfertigkeit in ihrer Abhängigkeit von der Verteilung der Wiederholungen.* For the suggestion that perseveration tendencies are heightened by rapid repetition, see Ephrussi, *Experimentelle Beiträge zur Lehre vom Gedächtniss,* same Zeitschrift, 37 (1905), p. 202.

Materials

Throughout the experiments, the material consisted of "normal" series of "English" nonsense syllables, made in imitation of the normal "German" series of Müller and Schumann.[10] A full description of the English series will be found in the writer's study of the reconstruction method.[11] Series of twenty-four

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[10] Müller and Schumann, *Experimentelle Beiträge zur Untersuchung des Gedächtnisses,* Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 6, pp. 99-106.

[11] *Memorizing by the Reconstruction Method,* pp. 20-23. In the series used in 1910-1911, *i.e.,* in the earlier experiments covered by this paper, the combination *qu* was introduced among the initial consonants. In the series used in 1911-1912, *i.e.,* in the last experiments covered by this paper and in all the experiments covered by the following paper, two additional changes were made. The digraph *th* was stricken from the list of initial consonants, because in aural presentation the sound was too easily mistaken for that of *f.* Further, before the terminal silent *e,* which was used to indicate a long sound for the central vowel, *c* was used to give the hard sound of *s.* *S* cannot be used before the silent *e* on account of its phonetic ambiguity and, therefore, in the earlier series the hard sound of *s* had not been used after a long vowel, although the soft sound had been given by *z.* (One could not tell from the spelling whether *bise* should rhyme with *wise* or with *mice* but *bice* is unambiguous.)

These series contain English words. So also do the normal series of Müller and Schumann contain German words. English series made by our rules have, however, at least this one merit, that a learner at all versed in the rules of English phonetics knows how to pronounce them when he sees them and can very easily learn how to spell them when he hears them. (The writer has seen in other laboratories such syllables as *qiv,* which seem unsuitable for most purposes.) It must be confessed, nevertheless, that not all laboratory workers are able readily to apply the laws of English phonetics and that nonsense syllables are in the case of English-speaking subjects by no means so satisfactory a material as they are in the case of German subjects. The German language is phonetic; English phonetic rules have members were made by joining two series of twelve, end to end, with care that no one sound should occur both in the twelfth and in the thirteenth syllables. The following may be given as a specimen series of twenty-four members: *quoke, pule, bouj, roin, jiv, lame, tene, mite, kug, wox, vesh, haz, moce, quag, poul, vube, hud, raje, shet, lif, keze, toim, wine, yosh.*

Method

Briefly described, our experiments consisted in learning and in relearning series of nonsense syllables by the method of complete memorizing, with aural presentation and with a variety of rates both of presentation and of recitation. In this section, it is necessary (I) to recall the details of the method to the reader's mind, (II) to state the exact manner in which the method was used in our own experiments, and (III) to set forth the procedures by which we strove to test the tenacity of the associations formed in learning the series.

I. The method of complete memorizing or *Erlernungsmethode* is the pioneer method for memory investigation which was devised by Ebbinghaus more than thirty years ago and was elaborated by Müller and Schumann in the early nineties. The writer has taken the term *method of complete memorizing* from Bergström.

The standard features of this method are as follows: A series of words or syllables is presented over and over again, either to the eye or to the ear of the learner, until he can once (or twice) recite the whole in order, without mistakes and without hesitation. At the end of any presentation,

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countless exceptions. Persons who have worked with the writer have persisted to the last in pronouncing certain syllables by analogy with English words not phonetically pronounced, *e.g.*, on making *pove* rhyme with *love* and *dove* instead of with *clove* and *stove*. Another unfortunate tendency is toward pronouncing the strange combinations of letters by analogy with French or German words. Thus, *bouj* may be made to rhyme with *rouge* and *jiv* may be called *yiv*. The writer can see no way of using a large number of different syllables without entailing these disadvantages upon the material.

the subject may begin to recite the series from the beginning, but as soon as he hesitates or makes a mistake, the rest of the series is presented to him. Thus, every repetition or traversing of the series, except the first and the last, may consist partly of presentation and partly of recitation. The first, which, strictly speaking, is not a repetition at all, is necessarily a complete presentation and the last consists in the unerring and unhesitating recitation. In all the publications of this laboratory, the term repetition is used (like the German word *Wiederholung*) to stand for any traversing of the series, whether made up wholly of presentation or wholly of recitation or partly of the one and partly of the other. In reading this paper, it is necessary to keep the distinction between presentation and recitation clearly in mind, since the rates of presentation and of recitation were varied independently of one another.

In the case of visual presentation, a recitation is counted as "unhesitating" when each syllable is named before it can be read by the subject from the revolving drum or other apparatus which is used to bring the syllables singly into view. When the presentation is aural, the distinction between hesitating and unhesitating recitation is harder to draw. The only general statement which can be made is that recitation is called unhesitating when the syllables are recited at the definite rate (however slow) at which the learner is required to recite them. In fact, "unhesitating" recitation is not an indispensable feature of the method. The essential points are rather (*a*) that the series should be repeated from beginning to end until the learner can recite the members in order, without mistakes and within a reasonable time, and (*b*) that when he has once made a mistake or abandoned the attempt to recite, the rest of the series should be presented to him without break. *Prompting* is foreign to the method of complete memorizing proper.

II. In our own experiments presentation was aural. The important details as to rate are as follows: (*a*) In presentation, the experimenter read the series (from the pages of her notebook) in time with the beats of a metronome. (*b*) The rate of recitation was in some of the experiments restricted and in others unrestricted. When the rate was unrestricted, the subject was allowed to recite the series at any rate she pleased, provided that she named the syllables correctly and in order. The total time occupied in the final recitation was taken with a stop-watch. (See p. 120 below.) (*c*) When the rate of recitation was restricted, it was the same for every series as the rate of presentation for that series. The subject was required to name the syllables upon certain beats of the metronome. (*d*) Altogether five different presentation rates were used. These rates may be called *very slow, slow, moderately slow, fast* and *very fast.* When the very slow, slow, moderately slow, and fast rates were used, the metronome was set at sixty, and the syllables were named respectively upon every fourth, every third, every second and each successive beat. When the very fast rate was used, the metronome was set at seventy-five and the syllables were named one to a beat. When the recitation rate was restricted, the syllables, as already implied, were recited as well as presented at four-second, three-second, two-second, one-second and four-fifths-of-a-second intervals. For the sake of brevity, the following symbols will often be used: *VSP* and *VSR* for *very slow presentation* and *recitation; SP* and *SR* for *slow; MSP* and *MSR* for *moderately slow; FP* and *FR* for *fast;* and *VFP* and *VFR* for *very fast presentation* and *recitation. UR* will be used for *recitation at an unrestricted rate.* (*e*) Whatever the rate of repetition might be, the following rules were followed: (1) At the beginning of work with each series, the experimenter said "Now" upon a given metronome beat and named the first syllable on the next beat but one. (2) At the end of any presentation, after naming the last syllable, she allowed one beat to pass and on the next beat said "Now." On the next beat but one after this signal, if the recitation rate was restricted, the subject was expected to name the first syllable and if she failed, the experimenter named it on the next beat after and then presented all the rest of the syllables at the proper intervals. (3) If, in any attempt at recitation, the subject made a mistake or failed to name a syllable on the proper beat or if, in the case of "unrestricted recitation," she said "I don't know," then the experimenter took up on the next beat the presentation of the rest of the series.

In all experiments made by the method of complete memorizing in this laboratory, the records have been kept in the following way: The series is written in a column at the extreme left of the page. A dot or cross is put to the right of each syllable as the subject names it correctly. A dash or "check" is put opposite the first syllable which the subject fails to name—a dash if no syllable is named and a check if the syllable given is wrong. The experimenter always begins with the next repetition a new and parallel column to the right. The number and character of the repetitions can thus be seen almost at a glance. In counting the number of repetitions, the first presentation is always excluded.

III. The tenacity or firmness of the associations formed in learning series at different repetition rates was gauged by the number of repetitions necessary for relearning. In interpreting this general statement, it is necessary to give certain details in regard to the intervals which elapsed before relearning and to note the two procedures which were used in measuring tenacity by the number of repetitions necessary.

a. Throughout the experiments, except in the case of the supplementary sets, the series were, as a rule, relearned two weeks from the day and approximately from the hour at which they were learned, each sitting being given entirely to learning new series or to relearning old ones. If, for example, series were learned on a given Tuesday, the work beginning at 2:30 p. m., the same series were relearned in the same order on the next Tuesday but one, the work beginning at the same hour. If the subject served twice a week, she had in the mean time learned about three times as many other series, one set, say, on the Friday of the first week, and two more sets on the Tuesday and Friday of the second week. Even if she worked only once a week, she had learned or relearned at least one other set of series between the learning and the relearning of any given set. It is important to note this fact for it is evident that the associations, whose firmness was tested, were weakened not merely by lapse of time but also by retroactive inhibition (*rückwirkende Hemmung*). This circumstance was a most undesirable complication but could not be avoided, if a reasonable time were to be allowed for the subject to forget the series learned and if a reasonable number of results were to be secured. As a matter of fact, the chief subject G. can remember a few series of nonsense syllables (without private review) pretty well for two weeks if no other series have been learned in the mean time, not well enough for perfect recitation without any fresh presentation but quite well enough for a perfect recitation after a single presentation. In a few instances, series were relearned three weeks from the time they were learned. This longer interval, which occurred only when entailed by inconvenient college holidays, was, of course, made to affect alike all sets of series which were brought into comparison. In the supplementary experiments in which the subjects were almost altogether untrained, the forgetting interval was one week, each subject serving three or four times a week.

Both in learning and in relearning, a compensating program, designed to equalize the effects of practice and fatigue for the different repetition rates, was carried out from week to week and as far as possible at each sitting.

b. If we take the number of repetitions necessary for relearning as the gauge of the firmness of the associations formed in learning series at different repetition rates, we yet may proceed in two different ways. (1) The series may all be relearned at the same rate at which they were learned. This procedure has the advantage of making it possible to measure in terms of the percentage of the original number of repetitions which is saved in relearning. The method, however, has serious disadvantages. If in experiments of this type the recitation rate is restricted, and especially if a rapid rate be prescribed, the subject is likely to break down in a certain number of recitations simply from fright. Thus to the repetitions, really necessary for memorizing, a certain fright-increment is added; and this increment, which is likely to be quite as large in relearning as in learning, obscures the saving in repetitions. Let us suppose that the subject, if emotionally calm, could learn the series with ten repetitions and relearn it with six. Suppose now that two extra repetitions are entailed in each case by stage-fright. This at once changes the proportion 6:10 to 8:12 and the percentage of saving from 40 to 33. If on the other hand, the rate of recitation is unrestricted, even the best of subjects is likely to take advantage of this fact and to allow his attention to slacken. This sagging of attention differs at different sittings and at different moments in the same experimental period. The question of recitation rate is a puzzling matter in experiments of the type under discussion. We shall encounter it again. Another certain objection to this first method of gauging tenacity will appear in the discussion of results. (2) The series learned at different rates may be relearned all at the same rate. In this case, some of them may be relearned at the same rate at which they were learned but some can not. It will, therefore, be impossible to measure tenacity by the percentage of repetitions saved but it will be possible to compare the numbers of repetitions necessary for relearning with one another as they stand. This method has no more serious objection than the fact that it multiplies the sets of experiments which it is proper to make—since all the rates used in learning should, theoretically, be used in relearning—and thus reduces the number of series which it is possible to have in each set.

The experiments fall into three main groups, beside a few supplementary experiments which were made on untrained subjects and need not be taken very seriously. The first and third main groups were made by the first method of procedure; the second group by a combination of the two. Our reason for returning in the third group to the first procedure was simply that we had obtained by it fairly definite results which we desired to test. The various combinations of rates in learning and relearning are shown in the following scheme, in which the abbreviations *Mem. 1* and *Mem. 2* stand for the *first* and *second memorisings*, and the letters *P*, *R* and *U* respectively for *presentation*, *recitation* and *unrestricted*.

Intervals in Seconds

Group I				*Group II*								*Group III*			
				Subgroup 1				*Subgroup 2*							
Mem. 1		*Mem. 2*		*Mem. 1*		*Mem. 2*		*Mem. 1*		*Mem. 2*		*Mem. 1*		*Mem. 2*	
P.	*R.*	*P.*	*R.*	*P.*	*R.*	*P.*	*R.*	*P.*	*R.*	*P.*	*R.*	*P.*	*R.*	*P.*	*R.*
4	U	4	U	4	U	4	U	4	4	4	4	3	3	3	3
1	U	1	U	1	U	4	U	1	1	4	4	2	2	2	2
				4	U	1	U	4	4	1	1	1	1	1	1
				1	U	1	U	1	1	1	1	0.8	0.8	0.8	0.8

A glance at the scheme will show that in Group II, two rates were used in the learning and relearning in all possible combinations, making four sets of experiments in all. Comparing two of these sets with each other, *viz.*, the slow-slow set with the fast-fast, one can measure retention by the first procedure. On the other hand, if one compares the slow-slow set with the fast-slow and the slow-fast set with the fast-fast, one can measure by the second procedure. The four different rate combinations were used *pari passu* according to a compensating program, and, hence,—*i.e.*, because the experiments with the slow-slow and fast-slow rates were not separated from the experiments with the slow-fast and fast-fast rates—it may be said that in this group the two procedures were combined. Unfortunately, the number of experiments in each set of this group is almost negligibly small.

Subjects and Experimenters

The details in regard to the personnel and dates of the experiments are outlined in the following scheme, in which a "period" means an experimental sitting of forty-five minutes.

Group I, 1910-1911, first semester. Subject, E. A. McC. Gamble—G. Two periods a week. Experimenters, Helen Forney—F.—and Florence Kunkel—K.

Group II

Subgroup 1, 1910-1911, second semester before Easter vacation. Subjects, G., F. and K., each two periods a week. Experimenters, G., F. and K.

Subgroup 2, 1910-1911, second semester after Easter. Subject and experimenters as in Group I.

Group III, 1911-1912. Subjects, G., two periods a week, and Josephine Curtis—C.—and Ethel Caution-Davis—D., each one period a week. Experimenter, Agnes Rockwell.

Supplementary experiments, 1910-1911, spring term. Subjects, eleven students in a first year course in psychology, who will be designated as Beginners or B. 1, 2, 3 and so on. About eight periods each, three or four a week, enough periods to learn about ten series each under each set of conditions. Experimenters, eleven other students from the same class, who had been laboratory partners of the several subjects throughout the year.

In the experiments made by G., F. and K. (Groups I and II), the work was done by two experimenters at a time, the one presenting the series and keeping the recitation record and the other taking the total learning time with one stop-watch and the recitation times with another. In Group II, subgroup 1, G., F, and K. served as subjects by turns, the other two persons acting as experimenters. (Each combination of experimenters was, of course, obliged to have ready a separate set of nonsense syllable series.) Miss Rockwell and the several beginners worked single-handed.

Of the various subjects and experimenters who took part in the main groups of experiments, F., K. and D. were seniors, pursuing a second full-year course in experimental psychology; C. was a second-year graduate student and assistant in the laboratory; and G. is the writer. The methods of memorizing peculiar to the individual subjects will be discussed in the section on results. Here it is sufficient to point out that all five subjects had had experience in making out the "normal" series of nonsense syllables and that all (for better or worse) knew something of the question at issue. All the five knew from the outset that the series were to be relearned. As a matter of fact, F. and K. served more extensively as experimenters than as subjects; C. was engaged in making the experiments reported in the following paper during the very months when she was serving as subject in this work; and D, was assisting C. (In this connection it may be remarked that Miss Rockwell, who in these experiments served as an experimenter, is the subject R. of the "fatigue work." (See p. 158 below.)

G. is the much-enduring subject G. of the reconstruction experiments, of the experiments by the method of complete memorizing which supplemented them, and of the preceding study in place associations. It is unfortunate that G. has been for so many years the only subject in our laboratory available for long series of memory experiments. The results, to be sure, have not always realized the expectation of this too-well-informed and too-much-interested subject. The objection to G.'s long continued service lies rather in the fact that the results obtained have only a somewhat "individual" value. G. has had from infancy a facility in *verbatim* memorizing exceeding at each stage the average facility of persons of the same age and degree of education, she has attained a very high level of practice, and she has also certain peculiarities of imagery and method which will be discussed in connection with the actual results of these experiments.

The subjects B. 1 to B. 11, who served in the supplementary experiments, were juniors and sophomores. They did not know when the series were first learned that they were ever to be relearned, nor were they familiar with nonsense syllables of any sort. The equally inexperienced experimenters did not make out the syllable series for themselves and were, of course, more or less prone to mispronounce them. All used the same carefully prepared series.

Results

The interpretation of the numerical results depends so much upon the subject's individual method of memorizing that the discussion of the introspective data cannot well be reserved for a separate section but will be merged with the discussion of the figures. Point by point, the numerical data will be followed by the introspective.

Group I. All series relearned at the same rates at which they were learned. Two rates of presentation, very slow—VSP, with *four-second intervals, and fast—FP, with one-second intervals between the syllables. Recitation rate unrestricted. Subject, G. Length of series, twenty-four syllables.*

The numerical results may be schematized as follows:

Series		*Learning*				*Relearning*				*Saving in*	
Type	*N*	*W*	*MV*	*LT* *Secs.*	*RT* *Secs.*	*W*	*MV*	*LT* *Secs*	*RT* *Secs.*	*W*	*LT*
VSP-UR	38	3.3	0.7	248	33	2.2	0.4	165	34	33%	33%
FP-UR	38	7.0	1.4	314	38	5.9	1.0	240	33	16	24

In this scheme and in those which follow, the letters *N, W, LT* and *RT* are used respectively for *number of series in the set,* for *average number of repetitions necessary for complete memorizing* (*Wiederholungen*), for *average learning time* and for *average final recitation time.* The first line of the scheme may be translated into words as follows: The subject learned and relearned 38 series at the very slow presentation rate (*VSP*) and recited them at an unrestricted rate (*UR*). She learned these series with an average of 3.3 repetitions and a mean variation of 0.7 from this average, and in an average time of 248 seconds; and she made her final recitation on the average in 33 seconds. In relearning, the average number of repetitions was 2.2; the mean variation, 0.4; the average learning time, 165 seconds; and the average recitation time, 34 seconds. Thus, in relearning, 1.1 repetitions and 83 seconds were saved on the average and these savings are 33 per cent respectively of 3.3 repetitions and 248 seconds. The fact has been already noted that in counting repetitions we have been accustomed to exclude the first presentation. The learning time was reckoned with a stop-watch from the *Now* which followed the first presentation to the moment when the subject pronounced the last syllable in her perfect recitation. Thus, *LT* includes the four-second intervals between repetitions and the two-second interval after the first *Now.* (See p. 113.) In taking the recitation times, another stop-watch was started on the *Now* which preceded each attempt at recitation. The values of *RT* are pretty exact; the values of *LT* are merely "gross" since the first watch was not stopped for interruptions of a few seconds' duration.

The figures in the scheme show the following facts:

1. Whatever the rate at which the series were presented, they were finally recited both in learning and in relearning in about the same time. *RT* varies only from 33 secs. to 38 secs. and this value approximates to the time necessary for reciting an *FP* (fast presented) series if recited at the same rate as presented, namely, 25 secs. If a *VSP* series of 24 members was recited at the same rate as presented, the time occupied would be 94 secs. (23 four-second intervals *plus* one two-second interval). From this uniform and moderately short *RT*, we may draw three conclusions: First, the subject preferred to recite the *VSP* series much faster than they were presented, evidently finding very slow recitation unprofitable and wearisome. Second, she could not have made her final recitation of the *FP* series in virtue of perseveration. Not only is the value of *RT* for the *FP* series too great in itself for perseveration-recitation, but it is even rather greater in the first learning than *RT* for the *VSP* series. Third, the subject had mastered the *VSP* and the *FP* series about equally well when she finally recited them. It is important to note before comparing the firmness of the associations in the two cases that we have to do with sets which were equally strong at the time of formation.

2. The *VSP* series were learned with a smaller *W* (average number of repetitions) and a smaller *LT* (average total learning time) than the *FP* series. The fact that the more slowly presented series were learned in the shorter time is only seemingly at variance with the ordinary finding (see p. 105 above) and is due to the unrestricted rate of recitation. The ratio of the times occupied in presenting the *VSP* and *FP* series is, roughly speaking, four to one (94 to 25). The ratio of the *W's* is a little less than one to two (3.3 to 7.0), for the learning and a little more than one to three for the relearning. If, therefore, the series had been recited at the presentation rate, *LT* would have been considerably longer for the *VSP* series. The series were, however, all recited at approximately the same rate and thus the case is reversed. The ratio of *LT* for the *VSP* series to *LT* for the *FP* series is a little less than five to six (248 to 314) for the learning and a little more than two to three for the relearning.

It is, therefore, perfectly clear that it was more economical, both as regards time and number of repetitions, for the subject to learn and relearn series at the very slow than at the rather fast rate of presentation. It is also evident that if the *VSP* series are remembered better than the *FP*, this cannot be due to the fact that the total learning time was longer for the former.

3. If tenacity is to be gauged by the fractions of the original work which are saved in relearning, then the *VSP* series were indeed remembered much better than the *FP*. The saving in *W* is for the *VSP* series 1/3; for the *FP* series, a little less than 1/6. The savings in *LT* are respectively 1/3 and a little less than 1/4. The fact that for the FP series the saving in *LT* is greater than the saving in *W* is probably due to the fact that in the first learning some of the series were very haltingly recited, thus making the first *LT* disproportionately long.

4. *MV* (the mean variation from the average number of repetitions) is noticeably smaller for the *VSP* series than for the *FP*. The uniform and very small numbers of repetitions in the case of the *VSP* series hints at a fact brought out by introspection, namely, that the subject used a technique in learning them which she was unable to make so useful in the case of the *FP* series.

Putting all these facts together, we may conclude (1) *that the FP series were remembered much more poorly than the VSP, but* (*2*) *that this fact is due not to the rôle played by perseveration in the recitation of the FP series but to some positive advantage possessed by the VSP series.*

The introspective statements recorded in connection with this particular group of experiments are scanty but are sufficient to show that the subject did not depart from her usual procedure in memorizing, which must be outlined here. As a memorizer, G. has two peculiarities. In the first place, she is a marked, indeed rather an extreme, case of colored hearing—to the best of her belief congenital and inherited. In the second place, she habitually localizes the material memorized by a sort of projection of images (spots of color) either in external space or in the internal field of vision. This habit has been much developed, if not acquired, by practice. In the original series of reconstruction experiments, localization became decidedly external but during the experiments here reported, the subject reverted to localizing in the internal field, when learning by the method of complete memorizing although she still projected the series upon the table during certain reconstruction experiments which were in progress, at the same time. During the experiments reported in the last paper, which were made a year or two earlier than these present experiments, the subject already showed a paramount inclination to internal localization although the conditions were designed to foster external projection. (See p. 83 above.) The subject's schemes of localization are plastic, sometimes change without volition on her part, and can be altered pretty readily at will, whereas the color of letters and combinations of letters (strictly speaking, of their sounds) has been fixed for all time within her recollection and has been transferred from one language to another. (During the third group of these experiments, she deliberately ceased to think of a series of twelve syllables as arranged in a horizontal line from left to right and chose to think of it as arranged in three vertical columns of four syllables each. On the other hand, she could no more make the green word *unity* red or blue than she could change the color of the grass on the campus.) She has, however, beside all this kaleidoscopic imagery, a full outfit of auditory-kinaesthetic images. These images serve to differentiate syllables which are the same in color, for although the syllable images are often particolored and sometimes show traces of black letters upon the colored ground, yet the subject has no well-formed images of letters or even of the shape of words as determined by their spelling. (A word is visualized simply as an oblong, ill-defined blotch of color, more or less long.) Thus, this subject presents in a marked degree many peculiarities of the visualizing learner and yet does not belong by any means to the pure type nor even to any normal mixed type. It may be added that, in anticipating a syllable, in recitation, its color is usually most steadily focused by attention. If the syllable is still "far off" and the recitation rate is slow, the auditory-kinaesthetic image may be clear, but if the time for anticipation is brief, the color touches off the actual *saying* of the syllable without the noticeable presence of even the most fragmentary internal speech. In the rapid recitation of a well-mastered series, many syllables are not anticipated at all but their colors appear as they are uttered.[12]

In all experiments in which G. has had to learn series presented at different rates, she has greatly preferred the more slowly presented series because the intervals allowed her time "to sort and group the syllables and get them into their places." By *sorting* is meant the clear perception and comparison of the elements of the syllables and by *getting them into their places* is meant visualization of the color spots in pretty definite positions in the external or internal field of vision and in very definite spatial relations to one another.

The foregoing description of G.'s method applies to all the groups of experiments reported in this paper and in that which follows. The records taken in connection with the group of experiments now in question show that G. followed her customary procedure, that she had nothing new to report as to imagery, and that she visualized the color spots as grouped by fours in a horizontal line running from left to right, and had to make special effort to clinch the last member of one group to the first of the next. They also show these two important points, first, that although G. preferred the *VSP* series, she used precisely the same method of grouping and localizing in both sets of series, and second, that she used no more mnemonic devices in the slow series than in the fast. They were "easier to make but less needed" in the slow series.[18] The fact that the recitation rate was unrestricted heightened G.'s preference for the *VSP* series, since it was not necessary to linger over the presentation of these series just because they were slowly presented.

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[12] On the imagery and learning methods of this subject, see *Memorising by the Reconstruction Method,* pp. 105 f., 115 f., and 184 f. See also p. 82 f. of these studies. This subject had also the honor of serving for Professor G. E. Müller and is described in his *Analyse der Gedächtnistätigkeit und des Verstellungsverlaufes,* Zeitschrift f. Psych. und Physiol. der Sinnesorgane, Ergänzungsband 8 (1913), pp. 184 f.

One or two additional points in regard to G. should be noted here. In the last few years (since 1910), her eyesight has become so poor that series of words or syllables can be presented to her only aurally if her learning time is to be closely compared with that of other subjects. Thus, aural presentation has been entailed upon whole groups of observers. Before 1910 she did not greatly prefer either aural or visual presentation. This fact is in itself an evidence of the plasticity of her localization schemes. She could with almost equal readiness visualize syllables according to any spatial pattern in which they might be presented or invent a scheme for herself. She has never been able, however, to image many color spots at once, even as arranged in a scheme so simple as one long line. The spots simply emerge here and there in definite spatial relations to one another, somewhat as objects come out in a garden at night when a spot-light is turned from one to another.

If now we bring the introspective results to bear on the numerical, we find the small numbers of repetitions and small variations, in the learning and relearning of the *VSP* series, fully explained. *The subject learned the VSP series more readily than the FP because she could more easily carry out her grouping and localizing procedure.* We do not, however, as yet find an explanation for the fact that the saving in time and repetitions was greater in the relearning of the *VSP* series. The two sets of series were mastered about equally well at the end of the first learning—the *VSP* series perhaps a little better, judging from the average recitation times,—but the *VSP* series, originally learned more readily, were relearned more readily in a disproportionate degree. The old groupings of syllables, formed with *less* pains, came back with *much less* pains, when the series were again presented. Unless the difference in firmness of associations is to be accounted for entirely by the rather shorter recitation time of the *VSP* series at the end of the first learning, then the *VSP* series have a superiority in the matter of firmness which calls for explanation. We shall, however, make no attempt to explain it until we see whether or not the findings of these experiments are confirmed by others.

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[18] By *mnemonic devices* or *auxiliary associations* are meant throughout these papers *not place associations* but a much more artificial class of extrinsic associations. Some of these devices are easier to make in the case of the more slowly presented series. An instance of this kind is the connection of the syllables *jiv, lame, tene, mite,* by the notion (partly pictorial rather than verbal) of *Jove's* kicking Vulcan out of Heaven and making him *lame* a *tiny* (*teeny*) *mite.* Other artificial connections are easier to make, or rather make themselves, when series are read fast enough to blend into pseudo-words or sentences. An instance would be the blending of *vesh, has* into *vicious.* For the division of auxiliary associations into *Assoziationshilfen* and *Aufmerksamkeitshilfen,* see Ephrussi, *op. cit.,* p. 77.

Supplementary Experiments.—Some very brief series of experiments made upon the subjects B. 1, B. 2 and B. 3 may be regarded as supplementary to the first main group. The results would scarcely be worth reporting if they did not illustrate certain possibilities in experiments of this sort. The general conditions under which these experiments were made are stated on page 118. The syllables in the series numbered twelve.

The numerical results are given in the following scheme:

Series Type	*Subject*		*Learning*				*Relearning*				*Saving in*	
		N	*W*	*MV*	*LT* Secs.	*RT* Secs.	*W*	*MV*	*LT* Secs.	*RT* Secs.	*W*	*LT*
VSP-UR	B.1	10	7.5	2.5	288	21	3.8	0.6	108	20	49%	63%
FP-UR		9	12.8	1.2	365	20	7.1	0.8	148	19	45	60
VSP-UR	B.2	10	5.5	1.6	264	24	5.3	1.0	127	21	4	52
FP-UR		10	12.2	2.6	330	28	5.5	1.9	147	27	55	55
VSP-UR	B.3	10	5.8	1.6	246	23	4.6	1.2	177	22	21	28
FP-UR		10	6.7	1.7	225	31	5.4	1.5	199	18	19	12

This scheme is to be read exactly like the scheme on p. 120. (*q.v.*). In looking at the figures one should note the following points:

1. The saving in *LT* and, in general, the saving in *W* is relatively great as compared with the figures for G. This fact is easily explained. These subjects had learned only these twenty series of nonsense syllables in the whole course of their lives and might well remember some of them for a week. In the case of B. 2 the saving in *W* is, for the *VSP* series, negligible, whereas the saving in *LT* is great. This means that the subject *recited* these series much faster in relearning than in learning, although the final recitation times are not very different.

2. Like G. all these subjects learned the *VSP* series with the smaller *W* and, with one exception for the first learning, with the smaller *LT*. For them also, learning with very slow presentation was more economical than learning with fast presentation, the rate of recitation being unrestricted.

3. As might be expected in the case of untrained subjects *MV* and *RT* are much more variable than with G. The variations in *MV* are not worth discussing but under *RT* it is important to note that B. 3 recited the *FP* series so much more slowly than the *VSP* at the end of the first learning that she cannot be supposed to have mastered the former as well.

4. B. 1 and B. 3 show the greater saving in *W* and *LT* in the case of the *VSP* series although the superiority of these series in this respect is not very marked. B. 2, on the other hand, shows a slightly greater saving in *LT* and a vastly greater saving in *W* in the case of the *FP* series.

If we turn to the introspection records, we find the cause of this difference between the subjects not far to seek. B. 2 claimed that she learned the series entirely in terms of auditory-kinaesthetic imagery and that with the *FP* series she was "nervous and bewildered." A glance at the figures shows that *W* in the first learning of the *FP* series was in her case very great as compared with the first *W* for the *VSP* series. Evidently, in the first learning, she had difficulty in apprehending syllables rapidly presented, whereas in the second learning, these same syllables were familiar to ear and tongue. Thus in the case of the *FP* series, the saving in *W* is great because the first *W* was particularly large. These figures illustrate a difficulty in gauging tenacity of associations by the amount of work saved in relearning. If with any set of series the number of repetitions required for the first learning is accidentally very high, then the saving of work in relearning is apt to appear large even though the series may not be particularly well remembered.[14] If, on the other hand, the first quotum of work is accidentally small, then the saving in relearning cannot in the nature of the case be very great. We shall later encounter this ***difficulty of the accidental first value of W*** in its second form.

B. 3 claimed both visual-verbal and auditory imagery and rather preferred fast presentation, finding the *VSP* series tedious. Since, however, she actually mastered the *VSP* series better in the first learning, it is not surprising that in their case the saving of work in relearning was the greater. B. 1 disclaimed visual imagery but adopted the expedient of naming her fingers with the syllables and was better able to use this device with the *VSP* series. All three subjects grouped the syllables to some extent but B. 2 and B. 3 do not seem to have projected them in any fashion. So far as these experiments go (which is certainly not very far), they appear to be roughly in line with the showing of the first main group.

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[14] It should be noted that the relearning of each series is done at a higher level of practice than the learning of that same series. This difference of practice levels is negligible in the case of slowly presented series but with rapidly presented series the unfamiliarity of series when first presented and their familiarity when relearned constitute a serious inequality of conditions.

Group II. Four sets of series: (1) series learned and relearned at the very slow presentation rate (four-second intervals); (2) series learned at the fast rate (one-second intervals) but relearned at the very slow rate; (3) series learned at the very slow rate but relearned at the fast rate; (4) series learned and relearned at the fast rate.

Subgroup 1. Recitation rate unrestricted. Subjects: G., F. and K. Series length: Twenty-four syllables for G. and twelve for F. and K.

The numerical results are presented in this scheme:

Series	*Type*	*Sub-*		*Learning*				*Relearning*			
Mem. 1	*Mem. 2*	*ject*	*N*	*W*	*MV*	*LT* Secs.	*RT* Secs.	*W*	*MV*	*LT* Secs.	*RT* Secs.
VSP-UR,	*VSP-UR*	G.	11	2.7	0.7	199	43	2.2	0.4	185	39
FP-UR,	*VSP-UR*		10	5.0	0.8	216	39	1.9	0.4	138	51
VSP-UR,	*FP-UR*		10	2.4	0.6	188	34	5.1	0.9	219	38
FP-UR,	*FP-UR*		11	5.0	0.5	220	38	4.5	0.9	199	36
VSP-UR,	*VSP-UR*	F.	12	4.5	1.0	201	14	3.3	0.5	143	18
FP-UR,	*VSP-UR*		8	10.6	2.1	319	15	3.4	0.5	125	19
VSP-UR,	*FP-UR*		8	5.5	0.9	228	17	6.3	1.3	169	23
FP-UR,	*FP-UR*		12	9.8	1.6	256	17	6.8	1.3	182	17
VSP-UR,	*VSP-UR*	K.	12	3.9	1.0	189	22	3.6	0.7	131	23
FP-UR,	*VSP-UR*		9	8.5	1.4	242	21	3.5	0.5	145	24
VSP-UR,	*FP-UR*		10	4.2	1.4	163	18	5.3	0.8	139	18
FP-UR,	*FP-UR*		12	8.3	2.1	240	25	6.4	1.0	186	26

This scheme is to be interpreted in the main like the scheme on page 120. Under the heading *Series Type,* the abbreviations *Mem. 1* and *Mem. 2* stand for the first and the second memorizings. No columns have been made to indicate the fractions of work saved in relearning because the series were relearned at a different rate from that at which they were learned, and, therefore, neither the numbers of repetitions nor, in strictness, the times occupied in learning and relearning are comparable.

The interpretation of the figures is such a baffling problem and the number of series in each set is so small that the writer is tempted to throw out the whole mass of results but is withheld from doing so by honesty since the results are not entirely in accord with the rather neat results of the first group of experiments. It should be noted that the results obtained from F. and K., even though the number of series is rather small, are more reliable than the figures obtained from the beginners. F. and K. had already served as subjects in experiments which might have been included in those of the first group if the number of series had been sufficient and which may, as they stand, be regarded as practice experiments for the work now in question. Aside from this fact, F. and K. were familiar with nonsense syllables and with the problem.

1. The first point to note is that in the case of G. there is much variation in *RT* as compared with *RT* in the first group of experiments. In the first learning, *RT* for the *VSP-VSP* series (series very slowly presented in both memorizings) is noticeably large, whereas in relearning, *RT* for the *FP-VSP* series stands out from the others by its great length, 51 secs. as against 39, 38 and 36 secs. This variation indicates a fact set down in the introspective records, namely, that in recitation G.'s attention fluctuated. This wavering of G.'s attention, which was, so to speak, an abuse of the unrestricted rate of recitation, led to the abandonment of it in the later experiments. It is *probably* responsible for the puzzling nature of the figures in G.'s case. *RT* is more uniform for F. and for K., to whom the experiments were relatively novel, and is much shorter for F. than for K. It is to be remembered that the series learned by F. and K. were only half as long as those learned by G. With this fact in mind, one can see that in the final trial, F. and G. recited at about the same rate—F. a trifle the faster—and that K. recited much more slowly than either.

The next important point is that at each learning very slow presentation was more economical than fast as regards time and, of course, as regards number of repetitions. Thus, for example, K. learned the two sets of *VSP* series in 189 secs. and 163 secs. respectively but required 242 secs. and 240 secs. for the two FP sets. She relearned the two *VSP* sets in 131 secs. and 145 secs. and took 139 secs. and 186 secs. for the *FP* sets. Moreover if we add together the times spent in learning and in relearning the same sets of series (see the figures in the two columns headed *LT*) we find that with one exception (in the case of G.), the entire time spent upon the *VSP-VSP* series is less than the entire time spent upon the *FP-VSP* series and that, with no exception, the entire time for the *VSP-FP* series is less than the entire time for the *FP-FP* series. These experiments, then, are in entire accord with those of Group I in showing that, with an unrestricted rate of recitation, presentation at four-second intervals was more economical than presentation at one-second intervals.

Nevertheless, in spite of the agreement between the two groups, we find the second group diverging from the first when we come to the question of percentages of work saved in relearning. The only series which can be compared as regards work-saving are, of course, the *VSP-VSP* and the *FP-FP* series. (The lines to be compared in the scheme are the first and fourth for each subject.) If we compare the percentages of the original *LT* which are saved in relearning, we find that with F. they are the same (28 per cent) for the *VSP-VSP* and the *FP-FP* series, that with G. the difference is negligible though slightly in favor of the *FP-FP* series (9% as against 7%) and that with K. alone it is decidedly in favor of the *VSP-VSP* series (37% as against 23%). The percentages of the original numbers of repetitions saved are for the *VSP-VSP* and *FP-FP* series respectively as follows: G., 19% and 10%; F., 27% and 31%; K. 8% and 23%. G.'s results are not really in sharp opposition to those of the first group. The saving in repetitions is still clearly in favor of the *VSP-VSP* series and the times are undoubtedly distorted by the subject's lack of attention. With F.

it is clear that neither set of series has an advantage over the other. All that can be said of K.'s results is that the difference between the values of *W* in learning and relearning seems anomalously small.

We now come to the second of the two methods of gauging retention, namely, the comparison of series learned at different rates but relearned at the same rate. (The lines to be compared in the table are the first with the second and the third with the fourth for each subject.) The results are certainly disconcerting. They speak decidedly for the better retention by G. of series rapidly presented. She relearned the *FP-VSP* series in a much shorter time than the *VSP-VSP* series (in 138 secs. as compared with 185 secs.) and with a smaller number of repetitions (1.9 as against 2.2). Similarly the *FP-FP* series have an advantage over the *VSP-FP* series (an LT of 199 secs. as compared with an *LT* of 219 secs. and a *W* of 4.5 as compared with a *W* of 5.1). With K., on the other hand, the *VSP-VSP* series retain the advantage over the *FP-VSP* series and the *VSP-FP* over the *FP-FP*. With F. the difference between the values of *W* is negligible and the *VSP-FP* series have a smaller *LT* than the *FP-FP*, but, as with G., the *FP-VSP* series have a smaller *LT* than the *VSP-VSP*.

Since the number of series in each set of this much divided subgroup of experiments is so small, it seems better to spend no more time in discussing the results until we see whether or not they are confirmed by the experiments of the next sub-group.

Group II, Subgroup 2. Conditions the same as in Subgroup 1, except that the recitation rate was restricted and made the same for each set of series as the presentation rate. Subject G. Length of series, twenty-four syllables.

The results are given in the following scheme:

Series	*Type*		*Learning*			*Relearning*			*Saving in*
Mem. 1	*Mem. 2*	*N*	*W*	*MV*	*LT* *Secs.*	*W*	*MV*	*LT* *Secs.*	*W*
VSP-VSR,	*VSP-VSR*	9	3.9	0.6	394	2.3	0.4	237	41%
FP- FR,	*VSP-VSR*	10	9.8	2.2	297	2.5	0.5	258	
VSP-VSR,	*FP- FR*	10	2.8	0.8	291	8.1	1.1	257	
FP- FR,	*FP- FR*	9	11.9	2.5	356	8.2	1.8	263	31

It is almost unnecessary to say that among the symbols under *Series Type*, *VSP-VSR, VSP-VSR* means ***very slow presentation and recitation, both in learning and in relearning,*** and so on. For brevity, the series will be spoken of as *VSP-VSP* series, and so forth. This scheme contains no *RT* columns, for since the recitation rate was restricted to the presentation rate the final recitation of *VSP* series had to take place in 94 secs., counting from the signal *Now*, and the final recitation of an *FP* series in 25 secs. The actual values of *LT* are all somewhat in excess of the times which would have been occupied if there had been no interruptions, such, for example, as were occasioned by the subject's breaking in to ask, "*Min* or *Nin?*" when she failed to grasp the first element of a syllable. To take an actual instance of divergence, the first *LT* for the *VSP-VSP* series should be 375 secs. and is 394 secs.

In discussing the results the first, though not the most important, point to note is that the slowly presented series no longer have a uniform advantage over the rapidly presented series as regards learning time. One set of series very slowly presented took longer in the first learning than either of the two sets rapidly presented. In relearning, one set very slowly presented took one second longer than one of the *FP* sets. Moreover, the total time spent upon the *VSP-VSP* series, in learning and relearning, is longer than the total time for any other set. It must be remembered that, in these experiments, the subject was compelled to recite the *VSP* series very slowly, whether she could have recited them faster or not, and that at the prescribed rate the recitation of a *VSP* series took upwards of four times as long as the recitation of an *FP* series (94 as against 25 secs.). Hence, *LT* for the *VSP* series cannot be as small as *LT* for the *FP* series unless *W* for the *VSP* series is only about one-fourth as great as *W* for the *FP* series. It will also be remembered that this subject, in the earlier experiments, made her final recitation of *VSP* and *FP* series in about the same time, namely, thirty-odd seconds. In face of these facts, we are compelled to conclude that ***there is little profit in comparing the learning times of series which must be recited at different rates.*** ***We never can tell how***

much faster than the slower rate the subject could have recited, nor, for that matter, what the consequences of artificial retardation may be in the way of inattention.

As regards *W*, the *VSP* series retain their old decisive advantage over the *FP*. Roughly speaking, *W* for the *FP* series is about treble the *W* for the *VSP* series. In these experiments, slow repetition appears to have accomplished, in proportion to the time spent upon it, nearly as much as fast repetition, though not more.

The *VSP-VSP* series have regained their old advantage over the *FP-FP* as regards the percentages of repetitions saved in relearning, 41% for the former and 31% for the latter.

Although the differences are small, the *VSP-VSP* series have in relearning a smaller *W* and *LT* than the *FP-VSP* series, and the *VSP-FP* series have the same advantage over the *FP-FP*.

In view of these facts, we must conjecture that in the experiments of the preceding subgroup, G., who confessed to fluctuating attention, was less on the alert in the relearning of those series which were really the more familiar, namely, those which were very slowly presented in the first learning.

F. and K. also served as subjects in these experiments, but as they learned only four series of each type, their results cannot be taken seriously. F.'s averages chance to be exactly in line with G.'s; K.'s are not.

The numerical results of this whole group of experiments are so scanty that little time need be spent upon the introspective records. The only important points in G.'s statements are her confession of slack attention (of "taking it easy") in the recitations of the first subgroup, and her remark that in the fast recitations of the second subgroup she sometimes "could not read the mental copy fast enough to get the syllables on the right beats", whereas at other times she purposely avoided "looking ahead" because if she "failed to see a color spot coming" (in its place on the line), she was frightened and apt to break down. This remark testifies to the paramount attention paid to the visual images of the syllables and to their spatial projection in the internal field.

F. and K. were both visualizers, also. K. made more use of internal speech than F. who instantly translated the aurally presented syllables into visual-verbal images and then often mispronounced them in reading them off. F. was "sure" she had auditory images "of the *g's* and *j's*," a declaration which certainly implies a dearth of auditory images. It is curious that F., who was the most exclusively eye-minded of the three subjects, was also the most rapid reciter. Both F. and K. grouped the syllables and F. projected them upon a horizontal line from left to right, grouping the first four together and pairing the next two and the very last two. K. used mnemonic devices both in the *VSP* and the *FP* series; F. used extremely few. K. like G., liked the *VSP-VSP* series best of the four sets, whereas F. preferred the *VSP-FP*, saying that in relearning it was tiresome to have to go over a series slowly when one already knew part of it.

Before we pass to the third and last main group of experiments, we should glance at the results of some experiments on beginners, which are supplementary to the work of the first subgroup of the present group, that in which the rate of recitation was unrestricted. The general conditions of these supplementary experiments are stated on p. 118. The following scheme gives sufficient indication of the series types used and of other details except the number of syllables in the series, which was twelve.

Series Mem. 1	*Type Mem. 2*	*Subject*	*N*	*Learning*				*Relearning*			
				W	*MV*	*LT* Secs.	*RT* Secs.	*W*	*MV*	*LT* Secs.	*RT* Secs.
VSP-UR,	*FP-UR*	B. 4	10	10.5	3.4	459	15	8.1	2.3	204	15
FP-UR,	*FP-UR*		9	16.6	3.7	405	14	7.4	1.5	176	14
VSP-UR,	*FP-UR*	B. 5	10	7.2	1.6	390	30	9.5	2.5	234	16
FP-UR,	*FP-UR*		10	15.0	3.6	513	27	11.1	2.9	267	20
VSP-UR,	*FP-UR*	B. 6	10	3.5	0.9	235	20	3.2	0.7	168	26
FP-UR,	*FP-UR*		9	6.2	1.4	307	17	3.9	0.8	178	28
VSP-UR,	*FP-UR*	B. 7	10	5.2	0.7	242	30	4.7	1.1	159	21
FP-UR,	*FP-UR*		9	8.4	2.0	318	24	6.0	1.3	205	20
VSP-UR,	*FP-UR*	B. 8	10	5.8	1.9	303	27	4.7	1.5	156	21
FP-UR,	*FP-UR*		9	10.6	2.4	475	26	5.6	1.1	188	22
VSP-UR,	*FP-UR*	B. 9	10	5.2	1.2	240	26	4.1	1.1	135	23
FP-UR,	*FP-UR*		9	9.1	1.9	265	29	4.3	0.8	108	27
VSP-UR,	*FP-UR*	B. 10	10	8.8	2.4	330	21	7.2	1.2	213	30
FP-UR,	*FP-UR*		10	14.1	2.9	375	24	7.2	1.4	195	15
VSP-UR,	*FP-UR*	B. 11	10	5.7	1.0	285	22	6.5	1.0	118	21
FP-UR,	*FP-UR*		10	7.9	1.3	283	22	5.0	1.4	169	16

In these experiments we find eight untrained subjects learning some series with a slow and others with a very fast presentation rate and relearning all at the same fast rate. All the subjects in the first learning mastered the *VSP* series with the smaller *W*, and all the subjects, except B. 4 and B. 11, had the smaller *LT* with the *VSP* series. From the values of *RT* we judge that all the subjects, with the probable exception of B. 7, knew the two sets of series about equally well at the end of the first learning. All, excepting B. 4, B. 10 and B. 11, relearned the *VSP-FP* series with the smaller *W* and all, except B. 4, B. 9 and B. 10, with the smaller *LT*. The differences are in some cases considerable. Only in the cases of B. 4 and B. 10 do we fail to find any advantage for the *VSP-FP* series over the *FP-FP*, either in the second *W* or in the second *LT*, and in the case of B. 10 the two values of the second *W* are equal. Turning to the introspective data, we find that only B. 4 and B. 10 expressed a preference for fast over very slow presentation. All the others objected to fast presentation because it made them "nervous" or because it made the syllables "a confused series of sounds" or because it "gave no time for review" (B. 7) or because it allowed less time for naming fingers with syllables. On the other hand, both B. 4 and B. 10 objected to very slow presentation as unnecessary and tiresome, though it should be noted that neither was a facile memorizer as compared with B. 6, B. 7, B. 8, B. 9 or B. 11. All these subjects except B. 9 were visualizers and all except B. 8 grouped the syllables in some fashion. B. 8 spoke of "reading off" the syllables but appears to have seen them in an unbroken line or column. All, except B. 7 and B 8, used some form of mnemonic device but no one of them, except possibly B. 7, made any great use of spatial associations.

From the second main group of experiments and its supplement, we may draw the following conclusions:

(*1*) *As in the first main group of experiments, the chief subject G. retained associations formed by the presentation of syllables at four-second intervals better than those formed by presentation at one-second intervals. This is shown by the comparison both of series learned at different rates and relearned at* *the same rate as learned and of series learned at different rates but all relearned at the same rate.*

(2) This better retention of the very slowly presented series cannot be considered a personal peculiarity of G., since we find unmistakable evidences of it in the fragmentary results obtained from other subjects. Nevertheless, the results obtained from F., B. 4 and B. 10 suggest that all subjects are not like G. in this respect.

(3) An unrestricted rate of recitation is dangerous in experiments of this type on account of the inequalities of attention which it permits and yet it is a convenience in giving us in the final recitation times a clue to the subject's relative mastery of different sets of series.

Group III. All series relearned at the same rates at which they were learned. Four rates of presentation: (1) slow —SP, with three-second intervals; (2) moderately slow—MSP, with two-second intervals; (3) fast—FP, with one-second intervals; and (4) very fast—VFP, with eight-tenths-of-a-second intervals between the syllables. Series recited at the same rate as presented. Subjects, G., C. and D. Number of syllables in series, twelve for all alike.

Series	*Sub-*	*Per-*		*Learning*			*Relearning*			*Saving*	*Total*
Type	*ject*	*iod*	*N*	*W*	*MV*	*LT* *Secs.*	*W*	*MV*	*LT* *Secs.*	*W*	*LT* *Secs.*
SP- SR	G.	*1*	18	2.9	0.6	107	2.6	1.0	96	10%	203
MSP-MSR			17	4.1	0.9	108	3.8	1.1	100	7	208
FP- FR			18	8.0	1.8	125	6.2	1.2	96	23	221
VFP-VFR			17	9.6	2.3	121	8.4	2.1	105	12	226
SP- SR		*2*	42	2.4	0.6	88	2.2	0.6	81	8	169
MSP-MSR			42	2.8	0.8	73	2.9	0.8	75	–	148
FP- FR			42	5.5	1.5	87	4.4	1.0	67	20	154
VFP-VFR			42	6.9	1.3	86	6.8	1.2	85	2	171
SP- SR	C.		23	4.7	1.5	176	4.0	0.8	149	26	325
MSP-MSR			22	6.1	2.4	162	4.5	1.2	119	18	281
FP- FR			23	9.9	2.6	155	7.3	1.9	114	26	269
VFP-VFR			24	14.0	4.0	177	9.0	2.1	113	36	290
SP- SR	D.		13	6.7	1.5	252	5.8	1.4	217	13	469
MSP-MSR			15	7.9	2.1	210	7.4	2.3	197	6	407
FP- FR			15	11.7	2.9	184	8.8	2.2	140	25	324
VFP-VFR			16	14.4	2.4	182	9.7	1.6	122	33	304

In this table, the times given under the *LT* headings are not the learning times actually recorded but times which have been calculated on the basis of the numbers of repetitions. The original records of these experiments were burned and the time averages were not entered in the table of results, which (with a scanty record of introspection) now remains in the hands of the writer. For practical purposes, the times entered in the table probably resemble the real times closely enough but they must all be slightly lower than the real times. (*Cf.* p. 132 above). For the convenience of the reader the values of *LT* in learning and in relearning have been added together and entered in a column at the extreme right of the table.

As the recitation times were restricted, the times occupied in the final and perfect recitation were respectively for the *SP, MSP, FP* and *VFP* series, 35 secs., 24 secs., 13 secs., and 10.4 secs., counting from the signal.

As represented in the table, the results of G. fall into two sections. The experiments covered by the first section were made before Christmas and the results worked out in the holidays. The outcome was so surprising to the experimenters that the results obtained after Christmas were averaged separately to see if they would make the same showing. When we scrutinize the figures, we see that they amount for G. almost to a reversal of the findings of the earlier experiments but that the number of series is so large that the work cannot be set aside. Moreover, the results of the other two subjects are quite in line with the new showing of G. In detail, the points to be noted are as follows:

1. As in the preceding experiments, *W* increases with the presentation rate. This is true for all the subjects, both in learning and in relearning, and is the common finding when series are learned at different repetition rates.

2. The more slowly presented series do not have such an advantage in *W* that they have an advantage in *LT* as well. We find that in each period of G.'s work, the learning times differ little among themselves and the relearning times still less. In the first period, the average total time spent upon the different sets

of series rises slowly but steadily with the rate—from 203 secs. for the *SP* series to 226 secs. for the *VFP* series. In the second period, the longest total time—171 secs.—was spent upon the *VFP* series, but the *SP* series are a close second, and then comes a considerable drop to the *FP* and *MSP* series—from 169 secs. to 154 secs. and 148 secs. In the cases of C. and D., the more rapidly presented series have a clear advantage in *LT*. With D., the advantage is very marked since *LT*, both in learning and in relearning, decreases steadily and, in relearning, decreases considerably with the increase of presentation rate.

3. As regards the percentage of work saved in relearning, the more rapidly presented series, not the more slowly presented, have in these experiments the marked advantage. With all three subjects the saving is least in the case of the *MSP* series. This fact is hard to explain and is very conspicuous. With G., the saving is greatest in the case of the *FP* series. In both sections of the figures, the advantage of these series is marked. In the first section, the difference between the *SP* and *VFP* series is negligible but, in the second section, the saving in the case of the *VFP* series is itself negligible. With C. and D., the *VFP* series show decidedly the greatest saving. In C.'s case, the *SP* and *FP* series rank together but, in D.'s case, the *FP* series are greatly ahead of the *SP*. In G.'s case, the numbers of repetitions are smaller, both in learning and in relearning, than those of the other subjects and the saving in repetitions is also less than theirs. The saving in repetitions is greatest with C., although her numbers of necessary repetitions are smaller than D.'s.

These surprising results raise three questions: (1) How is the divergence of G.'s results from those obtained in the experiments of the year before (Groups I and II) to be explained? To be sure, the numbers of series in Group II were not large but, on the other hand, those in Group I were considerable—thirty-eight in each set as against forty-two in the second section of these experiments. (2) Is the advantage of the more rapidly presented series in the cases of C. and D. (an advantage which is marked in comparison with their showing in the case of G.

even in these experiments) an indication of an "individual difference"? (3) What is the meaning of the fact that the *MSP* series, and not either the *VFP* or the *SP* series, show the minimum of saving in relearning? In the discussion of these questions such introspective data as remain in the possession of the writer will be interpolated.

(1) As regards the first question, it is probable that G.'s results are not really so much at variance with her showing in the earlier work as appears on the surface. Three facts are to be taken into consideration. In the first place, G.'s percentages of saving are, in these experiments, small as compared with her percentages in Group I and in the second subgroup of Group II. (See the schemes on pp. 120 and 131.) They are also small as compared with the percentages of C. and of D. As a matter of fact, G. was memorizing so many series at the time when this present work was done that her retention was very poor. She was serving as subject in the "fatigue experiments" described in the following paper and was very much aware of the displacement of one series of impressions by another. This fact does not explain the advantage of the *FP* series but simply shows that these experiments were made under conditions different from those of the preceding year, which were made when G. was learning no other series of nonsense syllables. In the second place, G. was, in these experiments, using somewhat different methods in learning the more slowly presented and the more rapidly presented series. With the slower series, she was using her old device of projecting the color spots which represented the syllables in a definite pattern in the mental field of vision. In the second section of these experiments, she ceased to project the spots in a single horizontal line and, for the express purpose of emphasizing spatial relations and comparing colors, took to projecting the spots in three vertical columns of four syllables each, so as to bring the first, fifth and ninth syllables, which were the initial syllables of each group, side by side from left to right in the same line, and so as to bring the syllables second in each group side by side in the line below, and so on. She tried to use the same method in the more rapidly presented series and had

usually succeeded in projecting the syllables before the final recitation. She had, however, a great deal of trouble in "hearing" the syllables of the *FP* and *VFP* series and, in her perturbation, caught at every mnemonic device within mental reach. If some of the syllables could thus be bound together and disposed of, her attention could be concentrated on "getting hold" of the rest. In relearning, these artificial associates frequently came back to mind, whereas the more slowly presented series often seemed entirely unfamiliar. The artificial associates differed from series to series; the framework of the syllable pattern was the same for all series and gave little assistance in reviving old impressions.[15] In the third place, we meet, in the case of the *SP* series, "the difficulty of the accidental first value of *W*" mentioned on p. 127 above. After all, G. was memorizing series of twelve syllables only and was memorizing at a slow presentation rate. This task had become very easy work for her. In the majority of cases, it was performed with two presentations. As the subject frequently remarked during the year in which these experiments were made, the first slow presentation enabled her "to take stock of the syllables in the series" and the second enabled her "to link them together." A third was entailed only by nervousness in recitation. But even in relearning these two presentations seemed to be necessary except when the subject was in exceptional learning trim. She had to "see what was in the series all the way to the end" before she could "connect it up." To put the matter numerically, the value of the first *W* had almost reached the lower limit for *W*, namely, one, and the value of the second *W* could not fall far below it. Putting all these facts together, the writer concludes that *in these experiments the superiority of the more rapidly presented series was accidental, and, therefore, that these experiments do not overturn, although they certainly do not support, the conclusions to be drawn from the earlier groups.*

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[15] The reader in these experiments was a Southerner of "opened vowels and softened consonants," and the subject, though of the Middle West by birth and speech, could not learn the syllables so well when they were presented by her as when they were presented by either of the two New Englanders who read in the "fatigue experiments." While she was learning the 70 series of the first section, she learned 116 series in the fatigue work, half of them *SP* and half *FP* series. *W* for the *SP* series was 2.7 as against 2.9 in these experiments, and *W* for the *FP* series was only 5.6 as compared with 8.0. It is evident that in the aural presentation of series, considerable inequality of conditions may arise through the provincial differences of pronunciation which are common even among educated persons.

(2) We must answer the second question in the affirmative. *In the cases of C. and of D., the advantage of the more rapidly presented series, not only in regard to total learning time but also in regard to the percentage of the original work saved in relearning, does really indicate a genuine individual difference between these subjects and G. The difference is probably rooted in the degrees of attention paid to the more slowly and to the more rapidly presented series.* The difference in attention may be traced to the difference in imagery. In one respect, this difference *may* have worked against the better retention of the more rapidly repeated series by C. and D. C.'s imagery, like G.'s, consisted of visual-verbal images (C.'s were of the normal type) blended with internal speech, but, unlike G.'s, C.'s imagery became decidedly auditory-kinaesthetic in the case of the more rapidly presented series. C. claimed expressly that, in the case of the fast series, she was helped by auditory-kinaesthetic "perseveration," that is, by the mental echo of the series in internal speech. Even G. remarked that sometimes a very rapidly presented series would seem to "say itself," but usually in the recitation of these series G. read from her mental copy and occasionally complained that the color spots would not form fast enough in the internal field. D. took a somewhat antagonistic attitude throughout the work and maintained that she "had no imagery at all" but that she could have visualized the syllables if she had liked the work. From this statement, we may glean, first, that she had little or no *visual* imagery and, second, that in reciting she took no pains to anticipate syllables. Her relatively short learning times in the case of the *VFP* series indicate that internal-speech perseveration came into play in her case also. Now the writer assumed at the outset of this paper that if series were recited with the aid of perseveration they might be recited before the associations between the syllables were firmly impressed, and

that such series would necessarily be quickly forgotten since perservation is essentially evanescent. If this assumption is correct, it is obvious that the better retention of the more rapidly presented series by C. and D. cannot be explained by the more conspicuous presence of the kind of imagery in which an aurally presented series most naturally tends to perseverate.[16] Indirectly, however, the difference in imagery was an important factor in determining the sorts of attention paid to the slower and to the faster series by C. and D., on the one hand, and by G., on the other. G. learned the slower series *con amore* because she could readily use her color-spot pattern. In presentation, the long intervals never seemed wasted because they were occupied in putting the syllables into their places in the pattern and in comparing the colors of syllables in different positions. In recitation, indeed, the long intervals were somewhat trying but not sufficiently so to make G. prefer the faster series. On the other hand, in the cases of C. and D., the long intervals were worse than wasted, since they evidently allowed time for attention to waver seriously. After a given syllable was presented or recited, the subject had time in a three-second interval to think of the next syllable, if she knew it, and then to think of something else, and she was apt to be thinking of that something else when the time came to hear or say that next syllable. C. expressed a marked preference for the faster series because the slower series were "hard to attend to." D. said that she "hated all alike," but evidently she did pay closer attention to the faster series. Otherwise the *FP* and *VFP* series could not possibly have had their great advantage in the matter of total learning time. Here, then, is the crucial difference between the subjects. C. and D. remembered the faster series better because they gave much more sustained attention to learning them and thus made stronger associations between the syllables. Unfortunately, we have, in this group of experiments, no comparable recitation times to serve as a clue to the strength of the associations when the series of the various sets were perfectly recited. The time of recitation was restricted and every series had to be recited just as fast and just as slowly as it was presented. *It is very probable that the difference in recitation rate led in itself to a difference in the initial strength of the associations, since the slow series could be recited in virtue of very weak associations.*

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[16] An eye-minded subject may undoubtedly have visual perseveration even in the case of aurally presented series, since the aural impressions may instantly be translated into ocular terms.

Incidentally and to complete the introspective data, it may be remarked that C. grouped the syllables in fours as did G., but made no mention of spatial projection. She used more mnemonic devices in the slower series than she used in the faster series, a fact which must in itself have made for the better retention of the slower series (actually less well remembered). D. does not appear even to have taken pains to group the syllables. She said that she was helped by artificial associations when they occurred to her but that she took no trouble to make them.

(3) The minimum saving in the case of the *MSP* series is hard to explain but Miss Rockwell makes the plausible suggestion that, in the cases of C. and D. these series were heard and recited with the least attention, since they required neither the effort to attend which was demanded by the still slower series nor the very alert attention which was necessary if the syllables of the faster series were to be grasped as presented and to be recited on the proper beats. This conjecture in regard to C. and D. is borne out by the fact that G. considered the learning of the *MSP* series particularly easy and pleasant. In the relearning, these series seemed more unfamiliar than any of the others to G., who said at the time that they were "hoodooed."

On the whole, then, we may conclude (*1*) *that this group of experiments gives no evidence that series of nonsense syllables slowly presented and recited are better remembered than series more rapidly repeated;* (*2*) *that, in view of the circumstances under which they were made, they should not be regarded as overturning the conclusion that G. remembered series learned by slow repetition better than those learned by fast repetition;* (*3*) *that two out of the three subjects certainly did remember the more rapidly repeated series better than those more slowly re-*

peated; but (4) that they did so probably because they paid better attention to the faster series and thus formed associations of superior initial strength. The experiments do not preclude the possibility that if these two subjects had really been able to recite the slower series as readily at the outset they might have remembered them as well as they remembered the faster series.

Conclusions

The conclusions to be drawn from the entire series of experiments fall into three sets: conclusions as to fact, conclusions as to theory and conclusions as to method.

I. The conclusions as to matters of fact have been summarized at the end of the discussion of each group of experiments and need only the briefest review here, since the reader can turn in an instant to the italicized sentences on pp. 122, 135-136 and 143-144. In a few words they are as follows:

a. The chief subject G., who is a predominantly eye-minded person and who projected the color images representing the syllables in a well-defined pattern in the mental field of vision, appears, under normal conditions, to have remembered the series of syllables which were very slowly presented better than those which were presented at a faster rate. This fact is brought out both (1) by the comparison of series relearned respectively at the same slow and fast rates at which they were presented and recited at an unrestricted rate and (2) by the comparison of series learned at different presentation rates but relearned at the same rate and all recited at the rate at which they were presented.

b. There were four other subjects with some degree of training, F., K., C. and D. The results obtained from F. and K. are too few to have much significance. The results of K., who like G. preferred the slow series, appear to be in line with those of G., whereas the results of F., who preferred the fast series, are not. C. and D., who served only in the experiments in which the presentation and recitation rates were the same and in which all series were relearned at the rates at which they were learned, remembered the faster series much better than the slower. D. visualized little, if at all, and C. made little, if any, use of spatial associations.

c. There is much reason to believe that whereas G. learned the slower and faster series (excepting perhaps the *MSP* series) with equally steady and tense attention, C. and D. paid better attention to the more rapidly presented series and had, therefore, linked the syllables of these series by a much stronger set of associations when the first learning was counted complete. The slow rates of recitation in the case of the more slowly presented series may well have concealed a weakness in the associations.

d. In certain rather fragmentary supplementary experiments, the majority of the subjects (who were untrained) appear to have remembered the slowly presented series better than those rapidly presented and there are hints that those who remembered the fast series better found it hard to attend to the slow series.

II. In passing to the theoretical conclusions to be drawn from these facts, the following points should be kept clearly in mind. The *strength* of an association is its *readiness* to function and is measured roughly by the association time, *i.e.*, by the time required for the recalled experience to emerge after the recalling experience comes to mind.[17] The lastingness or wearing-quality or "life" of an association depends (aside from individual differences in retentiveness) upon its initial strength and upon its freedom from retroactive inhibition, *i.e.*, from the dislodging effect of a later formed and very similar association. Its strength at any one time after it is formed and before it is obliterated or renewed must depend upon its initial strength and upon its freedom from retroactive disturbance, and upon the time which has elapsed since its impression. The initial strength of such a series of associations as is formed in learning series of nonsense syllables by the method of complete memorizing may, for our purposes, be reckoned as their strength at the end of the last repetition in the first learning. If the recitation rate is unrestricted and the learner is interested in "doing well" and, therefore, recites as fast as he can, then the recitation time offers a good rough gauge of the initial strength of the associations. But a restricted recitation time cuts out this gauge. A rapid rate of recitation demands pretty strong associations—unless they are helped out by perseveration. A slow rate, if prescribed, may or may not mask weakness in the associations. A rather slow rate of presentation, if *chosen* by the subject in the case of rapidly presented series, must indicate that they are not recited in virtue of the mental echo or, in other words, of perseveration.

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[17] Aside from the fact that individuals appear to differ in celerity of recall and aside from the fact that the real association time can never be gauged with entire precision, this time is not a perfect measure of the strength of the association, since it may be lengthened by reciprocal inhibition between this association and another. In fact, the strength of an association is best expressed by the probability that it will function sooner or later, a probability which can be gauged by the method of right associates, not indeed for one particular association but for each association as a member of a group formed under certain conditions. See p. 47, note of these Studies.

We are now ready to restate the main issue and to formulate the main conclusion of this study. Its chief interest lay in determining whether series rapidly repeated (*i.e.,* series quickly presented and recited either at this same quick rate or as fast as the subject chooses) are more quickly forgotten than series learned at a slow rate of repetition. If they are, then it may be inferred that the final recitation was accomplished in virtue of rather weak associations eked out by perseverative (or if one prefer, by *impressional*) tendencies. If they are not, then no tendencies which are in their very nature evanescent can have accomplished a recitation premature in the sense that it took place before the associations were clinched. Now we are forced to conclude that *it cannot possibly be inferred from these experiments both that quickly repeated series are remembered less well than slowly repeated series and also that their poorer retention is due to the fact that in the first learning the final recitation was achieved with the aid of perseveration. For, in the first place, in the only clear and well-substantiated case in which series presented fast were not so well remembered as series presented slowly (that of G. in the first group of experiments), the slow rate of recitation chosen by the subject precludes the possibility that perseveration played a very significant part. And, in the second place, we find that in those cases in which we may be pretty sure that the "mental echo" was present in the case of the rapidly repeated series, they were better remembered than those* *slowly repeated.* Thus, the main question of this study is settled in the negative in so far as these experiments can settle it. The reader will realize that the subjects were few and that the fastest rate of presentation and recitation (one syllable to eight-tenths of a second) was really not so very fast, though fairly rapid for the aural presentation of meaningless material.

Two or three questions of minor interest remain. In the first place, we have the task of explaining why G. on the whole remembered the slowly repeated series better than those rapidly repeated and of stressing the reason why this showing was reversed in the cases of C. and D. The answer to the question as to G. is probably as follows: She remembered the slow series better than the fast because slow presentation gave her more leisure for visualizing the spatial patterns in which she imaged the syllables and thus for forming criss-cross associations between them. These associations were less conspicuous in the case of the rapidly presented series, even though the associations between each syllable and the one next following were just as strong. For instance, although the associations between the first and second and between the fourth and fifth syllables were no stronger in the slow series than in the fast, yet the first syllable was more strongly associated with the fifth, which was imaged either beside it or in a corresponding position in the next group of four syllables (really of four color spots). These criss-cross associations (secondary associations intrinsic to the series), like the true mnemonic associations (which are secondary but extrinsic), are revived in relearning and appear to facilitate it. G. made no more mnemonic associations in the slow series than in the fast but she did dwell more on criss-cross connections. G. certainly did not in general pay higher-level or steadier attention to one set of series than to another although, as we have seen, the moderately slow series of the third group of experiments seem to have fared ill at the hands of all the subjects. Rapidly presented series cannot be mastered at all unless the learner strictly attends to business, and the slowly presented series were zealously attended to by G. because she took pride in keeping the number of necessary repetitions as low as possible, always hoping to make a perfect recitation after a single slow presentation of a twelve-syllable series and sometimes succeeding. On the other hand, C. and D. certainly paid closer attention to the more rapidly repeated series, thus disproportionately reducing the learning time. This fact would not explain the better retention of the rapidly repeated series if we could believe that the associations formed in learning the slow series were in the end equally strong. We have no numerical evidence that they were not, since in the experiments in question the slowly presented series had also to be slowly recited. Since, however, slow recitation was allowed, the series *could* be recited in virtue of weak associations. Since, moreover, C. complained that the slow series were hard to attend to and since D., throughout the experiments exerted herself as little as possible, we have much reason for supposing that the initial strength of the associations in the slow series was actually low. Superiority in the initial strength of the primary intrinsic or "intentional" associations (the associations between each syllable and the one next following) probably then explains the better retention of the quickly repeated series by these two subjects. This conclusion is, of course, in direct contradiction to the supposition which gave rise to this study.

In the second place, it must be frankly confessed that the experiments *fail to give the slightest indication of any physiological advantage in slow repetition—of any consolidation process as involved by it.* The advantage of the slow series in the case of G. is sufficiently explained by her peculiar method of memorizing. On the other hand, in the cases of C. and D., the disadvantage of slow repetition, namely, its failure to enforce steady attention, was great enough to *hide* a considerable physiological advantage.

Finally, it must be said that the explanation of the feeling of automatism which one has in reciting a rapidly and frequently presented and recited series must remain an open question. The series—often rather suddenly—rolls out before the mental eye or reels off in internal or actual speech as if the reciter were a mere reader or mouth-piece. This sort of thing does not seem to happen in the case of slowly repeated series. Why? One can scarcely explain it as a vocal-motor automatism because speech, whether internal or actual, is not always prominent in this self-thrusting of the series into consciousness. There are two possible explanations of the experience. (1) It may be that the associations, very strong because they are very fresh and repeatedly stamped, function so quickly that the learner suffers a slight emotional shock. (2) It may be that the mental echo is really a perseveration of the members, a perseveration forced into serial order by the associations between them. (*Cf.* p 108 above.) The question reduces itself to this: Are "impressional tendencies" more important in this phenomenon than in ordinary recall? If so, they produce all that the present writer means by perseveration. *These experiments show that such perseveration, if it exists, is less important in the recall of rapidly repeated series than the writer had supposed, but they do not explain away the feeling of suffering, or being passive under, the intrusion of the series members.*

III. The conclusions as to method the writer believes to be the only important contribution made by this study. Although she has clearly seen how her method might be improved, she has never made any more retention experiments of this type. At the end of this study, she had become completely discouraged in the attempt to make such experiments with undergraduate co-operation. Under the conditions of undergraduate life and work, it is absolutely impossible to secure the learning and relearning of a large number of series, under parallel conditions, by a satisfactory number of subjects. If, however, one has the temerity to make experiments similar to those described in this paper, the following points should be noted:

a. Parallel experiments should be made with a restricted and with an unrestricted recitation rate. An unrestricted rate is likely to have a dangerous effect upon attention unless the subject is taking a keen and unflagging interest in his work. On the other hand, the restriction of the recitation rate withdraws the invaluable gauge of the initial strength of the associations which is furnished by the recitation times, if the subject is allowed to recite the syllables without nervous haste and yet as fast as they occur to him.

b. Even if the recitation rate is to be restricted, slow recitation should not be required. In other words, the subject should be required to recite the slow series not at the rate at which they were presented but at the rate at which he recites the fast series. At first, a certain emotional disturbance is involved in passing from slow presentation to fast recitation, but this soon wears off. (This the writer knows by experience as subject in work which is not yet ready for publication.) If the series are all recited at the same rate, one can, of course, compare, as regards firmness of associations, only the effects of slow and of fast presentation and not the effects of the slow and fast traversing of the whole series, the part recited as well as the part presented. The first comparison, however,—that is, the comparison of presentation rates—is simpler and needs to be made before the more complicated comparison is attempted. In any case, the artificial lengthening of intervals in recitation permits and conceals the recitation of the series in virtue of weak and lagging associations, allows the attention of some subjects to wander, and tempts others to fill up the pauses by inventing far-fetched mnemonic connections or by making private reviews of parts of the series, reviews which are not counted in the numbers of repetitions which the experimenter guilelessly sets down in his record-book.

c. Of the two methods of gauging retention described in the section on method, the second is greatly preferable. That is, it is better to compare the ease with which series, learned at different rates, are relearned all at the same rate than to compare the fractions of work saved when series, learned at different rates, are relearned at the rates at which they were, respectively, learned. The objections to the latter method are perhaps three. The two certain objections have already been mentioned. In the first place, if the rate of recitation is restricted, the subject is as likely to be frightened in relearning as in learning and his fortuitous break-downs in relearning obscure the residual difference between the numbers of necessary repetitions and learning times. (For illustration, see p. 116.) In the second place, if the average number of repetitions is accidentally high in the first learning, as it is likely to be if the subject has difficulty in reading or in "hearing" unfamiliar syllables, then the percentage of work saved in relearning these same syllables, now more familiar, exaggerates the firmness of the associations formed in learning. If, on the other hand, the number of repetitions necessary to the first learning is approaching unity (as when G. was learning slowly repeated series of twelve syllables), it is numerically impossible that the saving in repetitions should be large. Lastly, it is at least possible that series learned and relearned at a slow repetition rate might appear to be better (or worse) remembered than series learned and relearned at a fast rate, not because they were *learned* at a slow rate but because they were *relearned* at a slow rate. In other words, if two sets of series were learned at the same rate but relearned at the different rates, those relearned at the slower rate might appear to be better (or worse) remembered than those relearned at the faster rate. It is very possible that one repetition rate more than another favours the revival of associations equally moribund when the relearning commences. In our experiments there is evidence neither for nor against this supposition, but if there be any truth in it, then, in a test of relative firmness of associations, series learned at different rates should be relearned at the same rate.

In conclusion, the writer wishes some one else joy in making similar experiments under conditions more favorable than she has been able to secure.

II

The Relative Amounts of Fatigue Involved in Memorizing by Slow and by Rapid Repetition

BY

JOSEPHINE NASH CURTIS

With the Assistance of Helen K. Goss and Ethel Caution-Davis

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Editor's Note

This paper contains the substance of a thesis which was presented by Josephine Nash Curtis in the June of 1912 to the Academic Council of Wellesley College in partial fulfilment of the requirements for the degree of master of arts. The outcome of the experiments was such as to justify the publication of the thesis only in a greatly abridged form. The work of cutting the text and of making shorter tables has been done by the editor with material assistance from Miss Goss. The editor has rewritten the conclusions *ex radice*.

II.

THE RELATIVE AMOUNTS OF FATIGUE INVOLVED IN MEMORIZING BY SLOW AND BY RAPID REPETITION

INTRODUCTION

In looking over the literature of experimental work in psychology, one can hardly help noticing with surprise how few of the many and detailed memory investigations have aimed primarily to discover the effect of the rate of repetition of the material to be memorized upon the difficulty of memorizing, whether this difficulty be measured by the number of repetitions or by fatigue. The general purport of such work as has been done is to show that a rapid rate increases the number of repetitions necessary for complete mastery, but decreases the total learning time; in other words, that, whereas each slow repetition accomplishes absolutely more, if considered with reference to the amount learned per repetition, each fast repetition accomplishes relatively more if viewed with reference to the amount learned per unit of time.[1]

The object of this paper is to present a comparison of the fatigue effects of memorizing normal series of nonsense syllables by slow and by rapid repetition. The question in regard to fatigue is two-fold: (1) Is fatigue more apparent when the subject memorizes by rapid repetition than when he memorizes by slow repetition? (2) If so, is the fatigue of memorizing at a rapid repetition rate so great as to cancel the time-saving effect of rapid repetition within the limits of a laboratory appointment lasting three quarters of an hour? A question of minor importance concerns the limit at which decreasing the rate of presentation decreases the number of repetitions necessary for memorizing and the limit at which increasing the rate of presentation diminishes the learning time. Ephrussi raised this question but gave a merely speculative answer.

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[1] See Ogden, *Untersuchungen über den Einfluss der Geschwindigkeit des lauten Lesens auf das Erlernen und Behalten von sinnlosen und sinnvollen Stoffen,* Arch. f. d. ges. Psychol. 2 (1903), pp. 163 f.; Ephrussi, *Experimentelle Beiträge zur Lehre vom Gedächtnis,* Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 37 (1905), pp. 183 f.; and Ebbinghaus, *Grundzüge der Psychologie,* zweite Aufgabe, pp. 671 f. *Cf.* also Jacobs, *Ueber das Lernen mit äusserer Localization,* Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 45 (1907), pp. 66 f.

To answer the first of the two questions primarily at issue, *viz.*, the question as to whether or not fatigue is more apparent when the subject memorizes by rapid repetition, one must solve the difficult problem of finding a simple yet efficient measure of fatigue. So many factors enter into fatigue that it is practically impossible to isolate one and test it, and it seems still more useless to attempt to find one test that measures all the factors at once. Then, too, individuals apparently differ to a great extent, both in the amount of work it takes to fatigue them and in the way in which fatigue affects them. The experimental study in fatigue is further seriously complicated by the methods employed by different experimenters in using the same test. This, indeed, sometimes makes it impossible to compare the results of different investigators. Tests of mental fatigue may be grouped in two ways: in the first place, as physical or mental; in the second place, as extrinsic or intrinsic. In the intrinsic test, fatigue is measured by the speed and accuracy with which the subject performs the same work that has fatigued him; in the extrinsic test, the fatigue is measured by his comparative efficiency in another kind of work. The extrinsic tests actually employed in this investigation were selected rather for their simplicity and variety than because of any unanimity in the conclusions of those experimenters who have used them. Of these the only physical test was with the dynamometer. The mental tests were: reaction time, and speed and accuracy in doing arithmetic.[3]

Subjects, Materials and Methods

The subjects used in these experiments were seven in number,—Miss Gamble, "G."; Miss Agnes Rockwell, "R."; Miss Florence Banks, "B."; Miss Cecilia Hollingsworth, "H."; Miss Evelyn Keller, "K."; Miss Marjorie Sawyer, "S."; and Miss Nathalie Williams, "W." All began work in October, 1911, except S., who was put in after the Christmas vacation to take the place of a subject whose results proved so erratic as to be absolutely useless for our purpose.

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[3] For a brief bibliography, including titles of experimental studies of fatigue, see pp. 189-190 below.

The only subject who had had much experience in such work was G., who was the principal subject of the earlier memorizing experiments in this laboratory.[8] In our work she served as subject two periods each week. It should be noted that in this paper the length of a period, unless otherwise stated, is to be understood as forty-five minutes. In Groups I and II of the following experiments, G.'s periods fell on different days; in Group III they were consecutive. Subjects H., K., and S. were all Wellesley College seniors taking a second course in experimental psychology; W., a junior taking the same course; and B., a senior who had had only one course in experimental psychology. All these subjects served one period a week for the year, except S., whose late beginning has already been mentioned. R., who acted as subject one period a week in Groups I and II and two periods a week (on different days) in Group III, was a senior taking the same second-year course.

In these experiments we used series of twelve nonsense syllables made in imitation of the normal series of nonsense syllables devised by Müller and his collaborators. These series are discussed briefly on page 110 of the preceding paper.

All the series were aurally presented and were learned by the method of complete memorizing. The rate at which a series was presented and recited was regulated by a metronome. The experimenter said "Now" on one beat of the metronome, waited a beat, and then began to present the series. In some experiments, the syllables were given on every beat, in others on every other beat, and in still others on every third beat. When the experimenter had finished reading the series, she waited a beat and on the next beat said "Now." The subject was then expected to repeat the series from the beginning, starting on the next beat but one, after the experimenter's" Now," and saying the syllables at the same rate at which they had been presented. If the subject failed to give a syllable on the proper beat of the metronome, the experimenter gave that syllable on the next beat and then presented the remaining part of the series at the prescribed rate. If the subject gave a wrong syllable on any beat, the experimenter interrupted her on the next beat with the correct syllable, accenting it strongly to impress the subject with the fact that she had given a wrong syllable. The experimenter then finished the series, waited a beat, and said "Now" as in the first presentation. Once more the subject tried to recite the series from the beginning and was, if necessary, prompted or corrected by the experimenter as before. This procedure continued until the subject succeeded in repeating the whole series correctly and on the proper beats of the metronome. The experimenter who read the series to the subject also kept the record of her attempts at reproduction by making columns of characters beside the series, each column corresponding to an attempt of the subject.

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[8] See pp. 82 f., 119 and 122 f.

Thus, by counting the columns of signs, we knew the number of repetitions necessary for complete mastery, and the characters enabled us to tell at what point in each repetition the subject broke off, and the nature of the failure. An assistant experimenter kept the time, starting the stop-watch at the reader's "Now" and stopping it on the subject's completing a perfect recitation (that is, a recitation correct and given at the proper rate) of the series. This second experimenter also kept the records of the fatigue tests.

Inasmuch as the point at issue was simply to discover which rate of repetition was more fatiguing, it was necessary to eliminate in the two sets of experiments (with slow and with rapid repetition) all differences other than rate which might possibly occasion differences in fatigue. The length of time required for learning a series is possibly an important factor. If, for example, it takes twice as long to learn a slow series as to learn a fast, and if the subject shows more signs of fatigue at the end of the slow, it would be impossible to say how much of the fatigue is due solely to the rate and how much to the fact that the subject's attention has been kept on a stretch for a longer time. It would also be impossible to say whether the results in the case of the "slow" series are influenced through genuine fatigue or merely through ennui. In order to eliminate as far as possible these difficulties, we endeavored to find two rates of repetition, one fast and one slow, which required approximately the same learning time. This proved not to be difficult, for we found from a few skirmishing experiments with all the subjects that as we increased the rate of repetition from very slow to very fast, the total learning time grew shorter and then again longer. It is evident, of course, that if one finds that a series given slowly takes no longer than a series given rapidly, it must be because the fast series is repeated too fast to save time. The question regarding the point at which increasing rate of repetition ceases to economize time is, it will be remembered, one of the secondary considerations of this study.

Our experiments fall naturally into three groups. In Group I, the preliminary experiments, the purpose was to discover at what two rates the subjects had about the same total learning time. In these we first gave the subjects series, as already described, at the rates 60/100, 60/75, 60/60, 60/30, 60/20 and 60/15. This method of differentiating between rates shows the relationship between the seconds occupied in giving a certain number of syllables and the number of syllables given, the numerator showing the former and the denominator the latter. For example, the rate 60/100 means that at this rate one hundred syllables would be presented in sixty seconds or, in other words, that the twelve syllables were actually presented at the rate of one syllable to every 6/10 of a second. We soon abandoned the 60/100 and 60/15 rates, as we found that the rate 60/100 was obviously too fast to economize time and that the rate 60/15 was obviously too slow to economize the number of repetitions. The sets of rates finally chosen for the different subjects were as follows:

G. 60/60 — 60/20
R. 60/75 — 60/20
B. 60/60 — 60/20
H. 60/60 — 60/30
K. 60/75 — 60/30
S. 60/75 — 60/30
W. 60/75 — 60/30

As will be seen later, the success of this plan was somewhat impaired by the fact that some of the subjects seemed to be affected at one rate by practice much more than at others.

When the rates to be used were finally determined, Groups II and III of the experiments were performed. In Group II, a number of fatigue tests were made at the beginning of the period, and were interpolated after the memorizing of every two series.[4] The experiments of Group III differed from those of Group II in the facts (1) that only one extrinsic test of fatigue was used, and (2) that a greater number of series were learned at each sitting, and that the subject's gradual loss of efficiency in memorizing was regarded as the chief index of fatigue. In these two groups, all the series presented in one day were given at the same rate. The rate to be used each day was determined according to a compensating program in order to prevent, as far as possible, series given at either rate from having the advantages of practice more than series given at the other rate.

We have outlined our procedure in performing the memory experiments and have differentiated between the three groups into which the experiments fell. We come now to the consideration of the fatigue tests. The results of all previous attempts to measure fatigue have proved so very contradictory that we decided, as already noted, to choose as many and varied extrinsic tests as seemed practicable in consideration of the time and apparatus at our disposal. The tests employed, for a longer or shorter period, were: (1) tests of muscular strength made with two different dynamometers; (2) tactile-reaction time; (3) auditory-reaction time; (4) free-association time; (5) a test of appreciation for rhythm made with a telegraph key, an electric pen and a kymograph; (6) a test of the delicate muscular coordination involved in needle-threading; (7) tests of speed and accuracy in arithmetical calculation. Tests 5 and 6 were speedily abandoned on account of glaring inconsistencies in the results. The arithmetic tests are the only extraneous tests which proved at all satisfactory. The procedure in the various tests was as follows:

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[4] At the very first, we introduced the tests after every series learned. However, we soon abandoned this procedure as we found that the tests often occupied more time than the learning of the single series, so that the fatigue at the end of a period might be due more to the tests themselves than to the memorizing. Of course, the tests in question, when made at the beginning of the period were not, properly speaking, fatigue tests at all but merely tests of normal efficiency.

The dynamometer.—In this test we used at first a piece of apparatus, consisting primarily of a suspended spring balance, described by Titchener in his "Experimental Psychology, Student's Manual, Qualitative," 1899, page 100, and manufactured by Stoelting and Co. This dynamometer proved useless, for even after limiting the performance so as to require the subject to keep the handle between the second and third joints of her fingers and to keep her feet off the floor (to prevent additional leverage from bracing), we found it impossible to be sure that the subject was using the same set of muscles all the time. The second dynamometer used was one of the elliptical-grip order, manufactured by Thomas A. Upham of Boston. With this instrument the subject was required to use only her right hand and to squeeze as hard as possible, and she was not allowed to stand in making the test.

Tactile-reaction time.—In this test we used Sanford's vernier chronoscope as manufactured by Stoelting.

Sound-reaction time.—Again we used the vernier chronoscope making the auditory signal by rapping sharply on the releasing key with a piece of wood. We made no specification in either of these experiments as to whether the reaction was to be sensorial or muscular.

Free-association time.—This we measured by a Hipp chronoscope connected in circuit with a fall-screen and a lip-key in such a way that when the screen fell, exposing the stimulus word on an upright tablet behind the screen, the circuit was broken and the chronoscope started. As soon as the subject dropped the lip-key by giving the reaction word, the circuit was made and the chronoscope stopped. The subject G. had difficulty in reading the words at the distance at which it was necessary to expose them and therefore had to have her stimulus words auditory instead of visual. In order to prevent the necessity of rearranging the apparatus for auditory stimuli the experimenter dropped the screen at the same time that she spoke the word. The stimulus words were all one-syllable nouns and only names of visible things were used. The reaction word of the subject was not recorded.

Appreciation of rhythm.—It was suggested at the beginning of these experiments that inasmuch as some authors[5] claim that the cause of many factory accidents is the loss of the appreciation of rhythm by the employees, it might be interesting to find whether mental fatigue would bring about any loss in appreciation of rhythm. To test this we required the subject to tap on a telegraph-key connected with a magnet pen which, as the key made and broke the electric circuit, traced a zigzag line on a kymograph. The subject was required to strike the key on certain metronome beats in a somewhat complicated rhythm which she was required to read into the beats of the instrument set at the rate 60/100. The results of the experiment, however, were absolutely negative, *i.e.*, no subject failed at any time to tap at exactly the right moments; and, therefore, no mention will be made of this test in the discussion of results.

Speed and accuracy in arithmetical calculation.—The first test was in addition of columns of the ten digits arranged by chance. The subject was required to add as far up a column as she could, in thirty seconds, with certainty of correctness. A record was kept of the number of digits added, the sum obtained, and the correctness of the answer. The second arithmetical test, used only in Group III and the only extraneous test in this period, was in the multiplication of the ten digits arranged by chance to form two five-place numbers. The subject was required to multiply the numbers as rapidly as possible with certainty of correctness. and a record was kept of the time taken and also of any mistakes made. The multiplication test was not introduced in Group III after every two series, as were the tests in Group II, but only three or four times in a period.

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[5] Bogardus, E. S. *The Relation of Fatigue to Industrial Accidents,* Am. Jour. of Sociol., 17, pp. 220-222; Brandeis, L. D., *Women in Industry,* Decision of the United States Supreme Court in Curt Muller vs. State of Oregon, Reprinted for the National Consumers' League.

Our experimental procedure has now been described. The methods used in the calculation of all the results of this investigation were as follows: Results of any one kind for different days of the experimental group were recorded in horizontal lines placed under each other so that the corresponding figures for any given task on all the different days could be readily added and averaged. For example, the numbers of repetitions required by G. for learning the first series given on each day were written in a vertical column; the figures for the second series were written in another vertical column; the figures for the first addition test were written in still another column, and so on. The tables and other numerical statements given in the next section are self-explanatory, except for the use of percentages. The extrinsic fatigue tests varied so much in units of measurement that it was necessary to find some common measure, if the figures for the different tests were to be properly compared. We finally decided upon the following procedure: The first performance of any given kind on each day, *e.g.,* the time taken for a tactile reaction before any memorizing had been done, was taken as the normal performance of its kind and was treated as unity. We next found the percentages of the first result that the figures obtained upon each of the succeeding trials represented. By this method we had all our results in the same terms (*i.e.,* percentages) and were able to compare the changes arising in the results of the various tests.

In most of the tests the results of all the subjects have been averaged together, as well as for each individual, and the results of all the subjects except G. and K. have also been massed apart from the results of these two subjects. The latter procedure seemed admissible in view of the fact that the results of B., H., R., and W. showed about the same trend. The results of G. and K. diverged decidedly and could not be included without obliterating all the significance of the averages.

Numerical Results

In this section the results of the extraneous tests and the signs of fatigue displayed by the changes in the numbers of repetitions necessary for learning the series will be considered. The results of Group II and of Group III will be discussed together as far as possible, since these groups, as will be remembered, differed not in general method or aim, but merely in the extraneous tests used and in the number of series learned in a period. The tentative nature of the first group of experiments has already been stated; the results for each of the many rates employed were few and need no further discussion here.

I. *Extraneous Tests*

Dynamometer tests.—Tests made with the spring-balance dynamometer (Stoelting's) proved entirely unsatisfactory on account of the different sets of muscles brought into play by the same subjects in different trials. Tests made with an elliptical-grip dynamometer showed for the principal subject G. no consistent change in muscular strength during the process of memorizing. The tests were therefore abandoned at so early a date that the results for the other subjects are too few to be discussed seriously.

Tests of reaction time.—The figures for auditory and for free-association reaction time are extremely inconsistent for each individual subject and have therefore been entirely discarded. The results of the tests of tactile-reaction time are parallel to those of the test with the elliptical-grip dynamometer: the subject G. showed no consistent increase or decrease of reaction time when memorizing either with fast or with slow repetition. The results for the other subjects are too few to be presented in detail. It should be noted, also, in regard both to the dynamometer and to the tactile reaction time experiment that the results for G. (in so far as they show anything) and the results for the other subjects (as far as they go) are in direct contradiction to one another. These results, therefore, have also been set aside.

Arithmetic tests.—In the addition test the results had to be calculated in a manner somewhat more complicated than that of the other tests, for we had to take into account not only the number of digits added in the given time but also the sum obtained. This was necessary because it is of course harder to add a number of large digits than the same number of small ones, and if the majority of the digits in a certain column happened to be large, the subject would not be able to add as many as if they had been small, but the sum obtained would be larger. The number of figures added and the sums obtained were added separately; the resulting sums for the different trials were then represented by percentage in the manner described on p. 165, the first percentage of each kind being treated as unity; the two sets of percentages were then averaged and the final average percentages are those taken into consideration. The results of G. diverge greatly from those of the other subjects. In memorizing by fast repetition she shows a steady decrease in the amount of work done, supplemented by a final spurt at the end. In the fourth addition test on each day (the test given after six series had been memorized) her efficiency is only 81% of her average efficiency at the beginning of a sitting. A terminal spurt is manifested in the rise of her efficiency to 88% in the fifth and last addition test. In memorizing with the slow series G. shows practically no change in ability to do addition. R.'s later efficiency percentages are always smaller than her normal and, on the whole, show more deterioration through memorizing by slow repetition. B. shows a steady decrease in amount of work done after the "slow" series and a very decided increase, falling off somewhat at the end, after the "fast." In the fourth of the addition tests, given in the course of memorizing by slow repetition, her efficiency percentage is only 69. In the third of the tests given in the course of memorizing by fast repetition, the percentage rises to 126 dropping to 106 on the fourth and last test. The averages obtained from the results of all the subjects, including G. and K., are worth little, showing merely that the subject's efficiency is never as great in the later trials as in the first, but exhibiting no difference between the results obtained in the course of memorizing with slow repetition and those obtained in the course of memorizing with fast, and showing no progressive change in efficiency in either set of experiments. If, however, the results of G. and K. be excluded from the averages it would seem that ability to add always deteriorates in the case of the slow series while in the case of the fast series it at first increases slightly and then decreases slightly. In the case of these tests, unlike the last two sets or reaction-time experiments, it is admissible to average the results of R., B., H., and W., for all show the same general trend. With one exception (H.) more mistakes were made in the arithmetic when the subjects were memorizing at the slower rate.

The multiplication test was the only extraneous test used in the third group of experiments whereas the addition test was one of a number used in Group II. The use of the multiplication in place of the addition test has the following advantages: (1) Closer concentration is secured; (2) the setting of a relatively difficult example in multiplication demands less space than the setting of a sum in addition. On account of this second circumstance, the figures could be written larger and variations between subjects due to differences in ease in reading the numbers could be avoided. In the multiplication tests we improved upon our procedure in the addition tests by measuring the time required for performing the task set instead of measuring the amount of work done in a given time.[6]

The multiplication test gives, in general, results which differ at many points from those obtained from the addition test. G.'s results show decrease in speed of multiplying after memorizing with rapid repetition and an alternation, probably accidental, between decrease and increase in speed after memorizing with slow repetition. Thus, G.'s results in the multiplication test fall fairly well into line with her results in the addition test. This assertion, however, cannot be made for all the other subjects. For example, R., who in the addition test lost efficiency in the case of both the fast and slow series, here in the multiplication test loses in efficiency in the fast series but gains in the slow, and B., who in the addition test lost in the slow and gained in the fast, here, in the multiplication test, gains in both. In the multiplication tests the results of B., H., S., and W. are all fairly consistent with one another and show a gain in efficiency with both the fast and the slow series. K. is, as usual, at variance with the other subjects and shows marked deterioration in the case of both slow and fast series. Thus, the figures from the two kinds of arithmetical tests taken in combination show little or nothing in regard to the fatigue-effects of the two rates of memorizing. G.'s results alone are consistent and, as we shall see, G. is probably the only subject (except perhaps K.) who suffered real fatigue. In the case of the other subjects, the variations are undoubtedly accidental.

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[6] Thorndike, E. L., *An Introduction to the Theory of Mental and Social Measurements,* p. 14.

The proportions of the total number of examples, done by all the subjects in a period, which show mistakes are as follows:

	Slow		*Fast*
Example I,	9%	Example I,	24%
II,	22%	II,	24%
III,	11%	III,	33%
IV,	8%	IV,	33%

That is, in general there were many more mistakes with the fast rate than with the slow. During the course of the experimental period with the slow series, the number of mistakes increases suddenly and then in the last trial decreases slightly; with the fast series, the number of mistakes made increases slightly. The discrepancies in the results of the extraneous tests are discouraging in view of the fact that the subject G., whose results are more numerous by far than those of any other subject, persistently differs from the other subjects in so far as the latter exhibit any common trend. It was exactly on account of the equivocal results furnished by the extraneous tests in Group II, that the only extraneous test used in Group III was the multiplication test just described. It is to be regretted, however, that the method of extraneous tests was not entirely abandoned, since, as will later appear, the best gauge of fatigue was the gradual deterioration of efficiency in memorizing, and since the interpolation of even one extraneous test gave the subject a change of occupation, arrested fatigue, and hampered us in the use of this intrinsic criterion.

II. *The Intrinsic Test*

The intrinsic criterion of fatigue is the change in the number of repetitions necessary for memorizing. The more important results of the investigation are presented in Tables 1 and 2. Table 1 exhibits, for the subject G., the numbers of repetitions necessary to learn the series arranged according to their time-position on the different days. Table 2 covers the corresponding results for the other subjects. Each one of these tables contains results from both the second and the third groups of experiments. The abbreviations *s* and *f* as used in the headings of both tables stand respectively for the "slow" and "fast" rates of repetition compared. The numerals in parenthesis after the *s* and *f* stand for the numbers of series represented in the averages.

As recorded in the tables, the results of all the tests seem meagre. It must be remembered, however, that the results have been separated according to their position in the series of tests made on each day (*Zeitlage*) and that, therefore, although really a great many experiments were made, there are but few results of any one kind. The most striking example of this is the work of the subject G. in Group III. G. learned 192 series of nonsense syllables, but the number of series learned at each rate and time-position is only 4. The results of subject G. (found in Table 1), and of R. and B. (found in Table 2) are the most noteworthy because G. and R. had had practice in working with nonsense syllables and so had no difficulty in apprehending them, and because the results obtained from these three subjects are more numerous than the results of H., K., and W. In Group 2, the results of the subjects, taken individually, are inconclusive. G.'s efficiency clearly deteriorated in the course of the period but not uniformly and not at one rate more than at the other. If a few scattering results obtained from R. on days when she happened to learn more series than usual be discarded, it is evident that the subject's ability to learn decreases rather steadily during the course of the day's experiments, with slow repetition, whereas with fast there is at times a slight improvement and at others a deterioration. R.'s loss of efficiency, however, is never as great with the fast series as it is with the slow. B. shows no loss of

Table 1

Subject, *G*

Group II			Group III											
Series	s (13)	f (12)	Series	s (4)	f (4)	Series	s (4)	f (4)	Series	s (4)	f (4)	Series	s (4)	f (4)
1	1.9	4.1	1	1.8	4.5	7	1.5	5.3	13	2.3	4.8	19	1.8	7.3
2	2.6	5.7	2	1.8	5.0	8	3.0	4.5	14	2.3	5.8	20	2.0	6.8
3	2.2	5.4	3	2.5	6.0	9	2.0	4.0	15	2.3	6.8	21	2.3	6.5
4	2.7	5.4	4	2.5	5.3	10	2.5	5.8	16	2.8	8.5	22	2.5	6.5
5	2.5	5.3	5	3.0	6.0	11	3.3	6.0	17	3.0	5.3	23	3.0	4.8
6	2.6	6.6	6	2.5	5.3	12	2.8	6.3	18	2.3	7.0	24	2.8	5.0
7	2.9	4.3												
8	2.4	6.6												
Average				2.3	5.3		2.5	5.3		2.4	6.3		2.4	6.1

efficiency during the period, but on the contrary an increase with both rates. This increase is greater with the slowly repeated series. The results of H., W., and K. are too meagre to receive more than passing comment. H. shows deterioration during the period with the slow series and, at first, improvement and then deterioration with the fast. W. shows improvement with the slow and deterioration with the fast. K.'s second trial shows, with the slow, an increase in the number of necessary repetitions; with the fast, a decrease. K.'s results for later trials show improvement to about the same degree for both rates. When the results of the subjects are averaged (whether with or without G. and K.) they seem to show that the subject's ability to memorize improves from the beginning of the period with the slow series, while, with the exception of a terminal spurt, it grows less with the fast series. No importance, however, may be attached to this seemingly definite result, for it is evident from Tables 1 and 2 that with such great individual differences an average is meaningless.

It will be remembered that in the experiments of Group II, a number of fatigue tests were interpolated after the memorizing of every second series. This fact justifies the suspicion that a or most of the subjects were spared real fatigue by the change of occupation. In the experiments of Group III, which have now to be considered, larger numbers of series were memorized without the interruption of a fatigue test. The multiplication test when it occurs, divided the series into groups.

In Group III, in considering the variations in the number of repetitions necessary for memorizing the series, the results will be treated first just as those from Group II were treated, and then afterwards, changes grosser than those from one single series to another, *i.e.*, changes from one set of series learned between two multiplication tests to another such set, will be discussed. The subject G., who was working a double period, learned twenty-four series a day. The number of series learned between the interpolated tests was six. This division into sets is plainly shown in Table 1 and the numbers of series in each set are averaged separately. In the case of the other subjects, the multipli-

TABLE 2

Subjects		R.		B.		H.		W.		K.		K New method		S.	
	Series	s (5)	f (5)	s (4)	f (3)	s (1)	f (1)	s (2)	f (2)	s (2)	f (2)				
Group II	1	4.2	12.4	5.5	9.0	9.0	14.0	16.5	9.0	10.5	20.5				
	2	5.4	12.2	4.3	9.0	9.0	9.0	6.5	22.5	12.5	10.5				
	3	6.8	13.2	4.0	7.7	10.0	13.0	7.5	14.5	11.5	22.5				
	4	4.8	15.2	3.3	8.0	11.0	15.0	15.0	30.5		22.5				
	5		11.4	4.5	8.7	10.0	25.0		12.5						
	6			4.8	8.7	14.0	12.0		19.5						
	Series	s (8)	f (8)	s (4)	f (4)	s (5)	f (5)	s (4)	f (4)	s (4)	f (4)	s (2)	f (2)	s (4)	f (4)
Group III	1	3.3	10.1	3.5	7.5	6.6	11.2	8.5	13.8	9.8	20.5	10.5	15.7	3.8	8.8
	2	3.9	11.3	3.5	7.5	6.8	10.8	7.8	12.0	7.8	17.8	5.5	16.7	5.8	12.5
	3	4.0	12.3	3.3	7.0	7.6	13.2	6.8	12.8	8.0	16.5	5.0	16.0	6.0	14.3
	4	4.1	10.5	2.8	7.5	8.0	15.2	6.3	13.3	8.8	26.8	8.5	19.3	4.8	10.5
	5	3.9	11.1	3.0	6.0	9.4	13.8	6.5	12.3	8.0	16.3	8.0	16.3	6.0	12.3
	6	3.9	9.9	4.0	7.0	9.6	14.8	8.5	13.3	13.0	15.0	13.0	15.0	5.5	14.0
	7	4.5	11.4	3.5	7.5	7.2	12.4	6.0	13.8					5.3	12.0
	8	4.3	10.4	3.5	7.0	8.2	13.2	7.8	13.8					5.5	12.8
	9	4.9	11.0	3.0	7.0									4.8	11.0
	10	4.0	10.8	4.7	7.7									6.3	11.5
	11			3.0	8.0									5.8	16.5
	12			4.5	7.3									6.8	11.0

cation tests divided the series memorized into halves or thirds. This division could not be shown in Table 2 but is indicated below in the text.

Treated by the first method, G.'s results are inconclusive. With two exceptions (series 7 in the slow set and series 9 in the fast), this subject on the average never learns any of the later series in the period in fewer repetitions than she needed for the first series. Her ability to memorize, however, does not deteriorate in any regular way. For the first fourteen series learned in a day greater deterioration is shown, in general, with the slowly repeated series, whereas for the last ten of a day's series greater deterioration is shown, in general, with the rapidly repeated series. The subject's explanation of the figures will be given in the paragraphs devoted to introspection.[7] R.'s results are apparently more positive. With one exception (series 6 in the fast set) her results show that the first series of a day is learned with fewer repetitions than are any of the succeeding series. The loss of ability to memorize, however, is always greater, for the slow series than for the fast. B.'s results show that her efficiency increases at first with both rates and decreases at the last with both rates. Much greater variations from the average number of repetitions required for learning the first series are shown in the slowly repeated series than in those repeated rapidly. H.'s results for both rates, except for a slight improvement in series 2 of the fast set, show deterioration during the course of a period's memorizing. This subject, however, shows practically no difference between the effects produced by the two rates, for both show a great loss of ability about the middle of the period and a final spurt at the end. H.'s slow series give results which are slightly more variable than those of her fast series. W.'s results show, with two slight exceptions, improvement during the course of a day's experiments. Her results for the slow series are much more variable than her results for the fast, and the improvement in ability to memorize is much more marked with the slow series. K.'s results, as first calculated, are inconclusive. The subject, however, changed her method of memorizing during the course of the experiments, and, if the results obtained under this new method alone be considered, we find a very decided improvement during the period, except for the last series with the fast rate. The results for the slowly repeated series are much more variable than those for the series rapidly repeated. The results of S. show with both rates an increase, during the period, in the number of repetitions necessary, or, in other words, a decrease in ability. In general this change is more marked with the slow series but the difference is slight.

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[7] *Cf.* pp. 31-32.

From the comparisons just made we gain very few conclusions. The most important is that with nearly all the subjects the results for the slow series reach values which differ more from the normal than the values for the fast series differ. The results for the different subjects may be contrasted as follows: G., B., and H. show no decided difference in the effects of the two rates, although B. improves with both rates and G. and H. deteriorate with both. R. and S. show greater deterioration with the slow rate though they also lose in efficiency with the fast. W. shows greater improvement with the slow rate though some improvement with both. K., like B., improves about equally with both rates except for a drop at the very end of the period when memorizing at the fast rate.

The results of Group III will now be treated by the second of the two methods mentioned above, the massing method. In order to compare the changes in efficiency caused by memorizing at the different rates, by larger steps than from series to series, the results of all the series which any subject learned between two successive multiplication tests have been averaged together and treated like the results of one series. This method of treatment gives the general trend of a period's work and avoids the confusion introduced by the more accidental variations in the individual series. It is unfortunate that the space available in Table 2 did not permit us to indicate the divisions for the subjects other than G. or to interpolate the group averages in the fashion in which the divisions and averages have been given for G. in Table 1. For the subject R. the size of the group is five; for B., four; for H., four; for W., four; for K., three; and for S., four. The group averages in order are: for R., in the slow series, 3.8 and 4.3, and in the fast series, 11.1 and 10.7; for B., in the slow, 3.4, 3.5 and 3.8, and in the fast, 7.4, 6.9 and 7.5; for H., in the slow, 7.3 and 8.6, and in the fast, 12.6 and 13.6; for W., in the slow, 7.4 and 7.2, and in the fast, 13 and 13.3; for K., in the slow, 8.5 and 9.9, and in the fast, 18.3 and 19.4; for K. with her "new method," in the slow, 8, 6.8 and 10.5, and in the fast, 16.2, 17.7 and 15.7; for S., in the slow, 5.1, 6.6 and 5.9, and in the fast, 11.5, 12.8 and 12.5. When massed in this manner, G.'s results show deterioration with the slow rate, becoming less marked as the period advances, and with the fast, at first practically no change and then great deterioration. R. shows a decided loss of ability with the slow series, a slight gain with the fast. B. shows steady deterioration with the slow rate, and with the fast, at first an improvement and later, a condition nearly normal. H. shows deterioration with both rates, but this is more marked with the slow. W. shows a slight gain in ability with the slowly repeated series, a slight loss with those rapidly repeated. K.'s results (if those obtained with the new method only be considered) show at first improvement and then deterioration with the slow and exactly the opposite with the fast. S.'s ability at first decreases to practically the same degree with both rates, and then decreases much more with the slow.

From this comparison it is evident that, when considered by large steps, the results of four of the seven subjects (R., B., H., and S.) show greater deterioration in the case of the slow series. R. and B., indeed, show deterioration with the slow rate, whereas with the fast rate the ability to memorize actually improves. W.'s variations from the normal are probably too small to have any meaning at all. G.'s results present a very interesting point. It is evident that during the first part of the work for the day (which in the case of G. alone lasted two consecutive schedule periods in Group III, instead of one period) G. behaved like the majority of the other subjects. In other words, if G. had served as subject for only one period at a time her results would have

TABLE 3

Subjects	Dynamometer		Tactile Reaction		Addition		Multiplication		Repetitions Group II		Repetitions Group III		Repetitions in Sections Group III	
	s	f	s	f	s	f	s	f	s	f	s	f	s	f
G.	?	?	?	+	?	−	?	−	−	−	−	−	−	−
R.	+	−	+	−	−	−	+	−	−	−	−	−	−	+
B.	+	−	+	−	−	+	+	+	+	+	+	+	−	?
H.	+	−	?	+	−	?	+	+	−	−	−	−		
W.	+	−	+	−	−	?	+	+	+	−	+	+	+	−
K.	?	?	?	?	−	?	−	−	−	+	+	+		
S							+	+			−	−		

agreed with the others. The following question then arises: Is the change in G.'s ability during her second laboratory period a characteristic of G. alone, or would this change appear with the other subjects if they memorized series for two consecutive periods? This question, unfortunately, cannot be answered. The reasons for the peculiarities of K.'s results will be considered in the discussion of individual differences.

It is evident that the showing of the series, when grouped, often differs somewhat from the showing of the series treated separately. One reason for this, doubtless, is that many subjects learn the second and third of a day's series more quickly than they learned the first. When the series are taken separately this change in ability stands out as an improvement. When the series are grouped this increase in speed simply raises the average of the first group of series, *i.e.*, of the normal, and so makes any deterioration in the later series more marked.

Table 3 will show at a glance the general trend of all these results. It will be convenient for the reader to turn frequently to this table in reading the following paragraphs, which deal, largely on the basis of introspection, with the individual differences between subjects. Two of the signs which are used explain themselves. *Plus* (+) indicates *improvement*, and *minus* (—) indicates *deterioration*. The question mark (?) stands for *no decisive change in efficiency*.

Introspective Results

In this discussion, introspective statements of the subjects will first be summarized. An attempt will then be made to explain some of the individual variations in the numerical results in the light of this introspective testimony. The introspective statements of the subjects relate to the following points:—the subject's sensorial type of memorizing, method of grouping, use of auxiliary (mnemonic) associations, preference as to the rate at which the series were presented, and opinion as to which rate required greater concentration of attention and which was more fatiguing.

As to the image types to which the subjects belong:—B. and

S. claim imagery almost purely visual, although from the rest of B.'s introspection it seems probable that auditory-kinaesthetic imagery also was important.[8] W. appeared to use visual imagery except when the syllables "came mechanically," that is, when speech movements appeared to be preceded by no anticipatory imagery. G. visualized the syllables as patches of color on which occasional traces of written letters appeared in black. (G. has colored hearing in a marked degree). However, she also made constant use of auditory-kinaesthetic imagery which was more noticeable in the case of the rapidly repeated series than in the case of those slowly repeated and which served to distinguish between syllables of nearly the same color. This subject noted a tendency to grasp the last two or three syllables of a series merely in auditory-kinaesthetic terms and to recite them in virtue of a "kind of echo." H. "tried to visualize" the syllables which did not readily suggest auxiliary associations. The syllables which did suggest such associations she apparently learned in auditory-kinaesthetic terms, visualizing only the persons or objects which figured in the mnemonic devices. R. learned principally, and K. wholly, in terms of auditory-kinaesthetic imagery.

As regards grouping, all the subjects attempted, more or less, to grasp the syllables in sets shorter than the series. G., K., and S. always divided the syllables into groups of four. H. arranged the syllables in five groups, with four in the first group and two in each of the others. B. grouped the syllables, when she first began to serve as subject, but soon discarded this procedure. B., usually, but not always, grouped the syllables by fours, and W. grouped the first four together and, if the series happened to be particularly hard, also grouped the other syllables by twos. As regards spatial projection, all the subjects testified more or less to having visual schemes into which they fitted the syllables. G., except in Group III, visualized the syllables as arranged in a row from left to right; in Group III she purposely changed from a single horizontal line to three vertical columns each formed of four patches of color. This change was made in order to make the spatial position of the syllables more marked as compared with one another. The subject used this scheme as much in the fast series as in the slow, but had, in the case of the fast series, greater difficulty in fitting the syllables into the proper places. The subject said that, in the case of the fast series, putting the syllables into their proper places was like sorting dishes and setting them in their places upon the shelves of a china closet. H. thought of the syllables as arranged in a row from left to right. S. said she projected the syllables on the wall in three columns of four syllables each.

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[8] *Cf.* statement of preference for fast series on p. 180.

Auxiliary associations were used by all the subjects. These associations consisted in general of "stories" woven about the series and names of people connected with syllables having a somewhat similar sound. G. memorized to considerable extent without use of such associations but always fell back upon them in case of difficulty and was, therefore, more apt to use them in the case of fast series than in the case of slow. B. also used auxiliary associations more in the case of the rapidly repeated series. R. and H., on the contrary, used them more in case of the slowly repeated series.

With respect to preferences for one rate over the other, it should be noted that R., B., W., and K. preferred the fast series; G., S., and H., the slow. R. and H. were particularly strong in their preferences. The reasons given by R., B., W., and K. for the choice of the rapidly repeated series are as follows: R., "It takes no effort to associate the sounds. They run in together and don't need auxiliary associations." (R., it may be noted, often sighed, when learning slow series, and complained of the monotony.) B., "The fast series are easier to connect with a story." (The subject probably meant that the syllables in the fast series were more suggestive of a sentence.) W., "The words say themselves. With the slow rate I had more time to think, and as soon as I thought very hard, I was lost." K., "The slow series gave me time to forget." In the words of B., W., and K., there are indications of perseveration, kinaesthetic or auditory-kinaesthetic, in the case of the fast series. The reasons given by G., S., and H., for the choice of the slowly repeated series are as follows: G., "With the slow series I could fit the syllables more easily into my scheme. Moreover, the syllables, which always appear in consciousness as spots of color, sometimes lag, and in the case of the fast series refuse to form in the mental field of vision before the metronome beat on which they are due. This experience is attended by very unpleasant organic sensations localized about the heart." G., however, confessed to having, not infrequently, the feeling of fright also, when learning the slow series. G. was ordinarily able to learn a slowly presented series in two repetitions and, realizing this fact, she felt considerable anxiety to keep the repetitions, at least on the average, at two. If, in any case, she exceeded two repetitions she tried desperately to learn the next series at the first hearing. S., "The slow series gave more time for recall and the experimenter pronounced the syllables more clearly at this rate." H., "I preferred the slow series because I had more time to work out my schemes for remembering." On the basis of these statements and of the other introspective data, it seems fairly clear that the subjects who prefer the fast series are, in general, those who are greatly assisted by kinaesthetic or by auditory-kinaesthetic perseveration, whereas those who prefer the slow series are, in general, those who rely chiefly upon visual imagery deliberately recalled.

It is evident that preference for one rate of memorizing over the other was not always coupled with better sustained efficiency in learning at the preferred rate. Although K. and W. both preferred rapid repetition, both showed greater deterioration when learning at this rate, and although H. and S. preferred slow repetition, these subjects showed a greater deterioration in learning the slow series. The deterioration of H. and S., in the slow series, may have been due to the fact that the difficulty of the task was not sufficient to keep their attention at high level. R., W. and K., who preferred the fast rate, expressly said that with the slow rate, their minds tended to wander. G., who preferred the slow series, showed in the first of her two periods greater deterioration with these series. G. explained her deterioration during the first period as follows: At the beginning of each sitting, when her mind seemed "like a freshly washed blackboard" on which every impression stood out distinctly, she could always learn a series with a relatively small number of repetitions (a *very* small number, usually two in the case of the slow series). However, when a number of series had been learned so that the mental blackboard seemed "clouded with erasures of every other series," the number of repetitions suffered an increase, which in the case of the slow series was large in relation to the very small number necessary at the beginning. (If the number of repetitions be two, an increase of one, the smallest increase possible, is an increase of fifty per cent.) Thus, two factors probably come into play in producing the appearance of greater deterioration during the first period in the case of the slow series: First, the arithmetical fact just stated, and second, the greater effort which the subject made to learn the slow series with a very small number of repetitions. This last circumstance may have brought about a genuine and considerable loss of efficiency.[9]

In regard to the feeling of fatigue, direct testimony is meagre. Only three times did any subject report feeling much fatigue at the end of the period. One day early in the year B. remarked that for the past two weeks she had been learning at the slow rate and that at that rate she had made a story, as she went along, to fit the syllables. When, however, on the day in question she had changed to the fast rate, she had become nervous, and at the end of the period felt weak and rather "seasick." The numbers of repetitions required for learning the successive series on that day were: 11, 6, 5, 6, 5, 5, 7, 5, 6, 8, 12, 7. G. reported marked fatigue on two days on which she learned twenty-four and twenty-eight series, respectively, at the fast rate. At the end of one of these periods this subject said that she felt weak and dizzy. The numbers of repetitions required for that day were: 5, 8, 4, 5, 5, 3, 4, 5, 4, 5, 4, 6, 6, 7, 4, 7, 5, 7, 8, 9, 4, 7, 3, 4. The day on which G. complained most of fatigue the following numbers of repetitions were needed: 3, 5, 8, 5, 6, 7, 4, 6, 3, 4, 9, 8, 6, 8, 7, 8, 6, 4, 5, 5, 8, 6, 4, 7, 4, 9, 8, 7. The subject began the work of this day in a condition of slight general fatigue. By the second set of six series her head began to swim and she felt more and more weak and dizzy until the third set of six series when she felt faint and sick. In the fourth set she felt better than in the third, but toward the end began to feel numb and tremulous, and her heart began to beat irregularly. In the last set G. felt better, but was almost too exhausted to complete the arithmetic at the end. Symptoms of fatigue persisted two or three hours after the experimental sitting. In view of this experience of G., we may safely say that her deterioration in the second period when learning by rapid repetition was due to genuine fatigue. Although K. did not complain of being tired, yet she was in delicate health throughout the year and suffered from time to time with severe neuritis. It is also worth noting that W. had a nervous breakdown before the end of the year. K. and W., it will be remembered, both preferred the fast series and yet showed greater deterioration in these series, which obviously put a greater strain upon the attention. On the whole, the introspection of the subjects, taken together with the small amount of deterioration which their work at each sitting exhibited, seems to show that G. (in the second of her learning-periods) and possibly K. and W. were really tired but that they were the only subjects who were fatigued at all. Such loss of efficiency as occurred in the other cases, if due to fatigue, was not due to a fatigue marked by unpleasant subjective symptoms.

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[9] *Cf.* pp. 174 and 176 above.

Data in Regard to Practice, Momentum, and Initial and Terminal Spurt

The main part of the discussion of the results of this investigation is now finished, but before summarizing the conclusions two other points of no small importance must be considered: (1) the influence of practice upon memorizing by the two rates of repetition, and (2) indications of initial spurt, of momentum, and of terminal spurt as they appear in the third group of experiments. It is impossible to trace these factors in Group II because at each sitting the memorizing was so broken up by the interpolation of fatigue tests.

Practice.—In the discussion of the method of making the experiments, the statement was made (page 161) that we tried to use two rates of presenting the series which would take approximately the same total learning time. As the experiments continued it became evident that most of the subjects improved in memorizing at the fast rates more than they did at the slow rates. Inasmuch, as at the beginning of Group II, series presented at the different rates occupied practically the same total learning time, the differences in the times occupied in Group III show the extent of the influence of practice. In Group III, G. learned a slow series in about 129 seconds on the average, and a fast series in about 110 seconds. For the other subjects the corresponding figures are as follows: R., 187 and 149; B., 175 and 133; H., 237 and 224; K., 279 and 261; K., new method, 258 and 226; W., 230 and 186; S., 174 and 168. The difference in the total learning times necessary for the rapidly and slowly repeated series is very marked with all subjects except S. It must be remembered, however, that S. had served as subject at least ten weeks less than the other subjects had served, and therefore practice in her case naturally would be less marked. An important feature in the practice gained with the memorizing was improvement in apprehension, *i.e.*, in ability to grasp the syllables when presented to the ear. This improvement was particularly noticeable with the fast series. Therefore, the effect of practice was more marked with this rate. Thus, practice in some cases defeated the intention of the experimenters to equalize the actual expenditure of time in memorizing fast and slow series. The inequality of learning time for the two sets of series suggests an unfortunate possibility in regard to the figures which evince deterioration in efficiency. Some of the subjects showed greater loss in the slow series and some in the fast. It may be that the slow series tended to fatigue the subjects R., B., and W. in virtue of the long continuance of the strain upon the attention. This supposition is borne out by the fact that these subjects expressed a distaste for the slow series. On the other hand, the fast series may have tended to fatigue other subjects in virtue of the high degree of attention demanded and the emotional excitement involved in "catching" the syllables. The comparative degree of fatigue in the two kinds of attention-strain may be a matter of individual differences and these individual differences may obscure the main issue in regard to the fatigue effects of memorizing by slow and by rapid repetition.

Initial Spurt, Gathering Momentum, Decreasing Momentum and Terminal Spurt.—Most experimenters seem to agree in spite of the varying methods used and the different conclusions drawn that mental activity shows a well-marked periodicity. There is no fixed normal type of daily rhythm, each person being apparently a law unto himself. Nevertheless, as to quantity, in any piece of steady work, most subjects exhibit the following stages: initial spurt, or else preliminary inertia with gathering momentum, decreasing momentum, and terminal spurt. If a pause or change of occupation is introduced in the course of the experiment, the work immediately after the interruption is often better and but very seldom worse than the work just before it. The quality and the quantity of work do not always vary in the same direction and degree. In general, in the period of decreasing momentum, the third of the four stages just mentioned, the changing relations between quality and quantity of work exhibit three chief moments: (1) quantity increases, quality decreases; (2) quantity also decreases; (3) with some subjects the quantity gets less and less, with others it increases under nervous excitement until exhaustion is reached. These phenomena can be traced only in the experiments of Group III and in this group only when the results are treated by the massing method.[10] In general, the slow series with all the subjects show the same trend in their variations—for the second of a set, a decided loss of ability; for the third, a decided improvement over the second (in the cases of H. and W. the results of the third series show higher ability than even the results of the first); for the fourth, loss of ability much less marked than that for the second series. G. and R. are the only subjects having a fifth or sixth series in a section. G.'s results show a yet further deterioration of efficiency for the fifth series, and an improvement for the sixth. R.'s results exhibit improvement for the fifth series. The results for the fast series show more individual variations than do those for the slow. All subjects except W. show loss of ability for the second series, and no subject shows marked recovery before the fourth series. With the fourth series the results of R., B. and S. show improvement over those of the second and third series, but the results of G., H., and W. show still greater deterioration. G. shows increase of ability with the fifth series and a slight decrease with the sixth. R.'s figures for her fifth series are indecisive.

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[10] See pp. 172 and 175 above.

These results therefore exhibit: (1) in the case of the slowly repeated series the stages of initial spurt, with most subjects gathering momentum; and with G. and R., terminal spurt; (2) in the case of the rapidly repeated series with all except W., initial spurt; with G., R., B., and S., late in the group, gathering momentum, and with G. and R., decreasing momentum. It is, of course, possible that all the subjects would have shown all the stages if all the sections had contained enough series.

These results are important in showing the disadvantages of extraneous tests, for in the sets of series between the tests the subjects seem to pass through most of the stages of efficiency. These stages, particularly that of initial spurt, evident immediately after the extraneous tests, obscure the general trend of the fatigue effects which might appear in the course of the period.

Conclusions

The first conclusion to be drawn from the investigation as a whole is that the extraneous tests proved distinctly unsatisfactory. The arithmetic tests appeared most reliable, the multiplication tests showing fewer individual variations than any of the others. This may be due to the fact that this was the only one which was used after the subjects had had considerable practice. It is possible that the other extraneous tests would have exhibited fewer individual variations if they, also, had been used in Group III. It is puzzling that there should be deterioration in muscular strength and loss of efficiency in adding with most of the subjects, when the numbers of repetitions necessary for memorizing showed so little variation. We must conclude either that the variations in the strength of the grip and the speed of arithmetical calculation were due to factors other than fatigue (a supposition which discredits their reliability as fatigue-tests), or that fatigue manifested itself in these extraneous tests before it was apparent even in the numbers of necessary repetitions.

A second conclusion is that the extraneous tests were not merely in themselves unsatisfactory but that they were also subversive of the main purpose of the investigation. Whatever advantages these tests may have in indicating fatigue is more than counterbalanced by the fact that they furnish change of occupation and retard the onset of the condition which they are supposed to test.

A third conclusion is that the subjects (G., H., and S.) who made much use of visual imagery in these experiments preferred the series learned by slow repetition, whereas the subjects (B., R., and W.) who appear to have been greatly aided by auditory-kinaesthetic perseveration preferred the series learned by fast repetition.

The fourth and main conclusion is negative, for as regards the chief issue our results are altogether indecisive. If we had not used the subjects G. and K., we should doubtless have supposed it perfectly clear that memorizing with slow repetition is more fatiguing than memorizing with rapid. The results of these two subjects, however, prevent the drawing of such a conclusion. There are three possibilities in the interpretation of the numerical results: (1) that none of the subjects were fatigued at all; (2) that all of the subjects were fatigued, but were affected in different ways; (3) that some only of the subjects were fatigued. From the consideration of our introspective results it is clear that the first of these possibilities was not realized, for B. and G. reported feeling greatly fatigued at the end of certain laboratory periods. The second of the possibilities—namely, that all the subjects were fatigued, but were affected in different ways—can scarcely be true, for the subject S. declared that neither rate fatigued her and that she would have enjoyed learning twelve more series each day. Furthermore, except in the cases already described in detail, the subjects practically never made remarks indicating that they were tired or even bored.

If, then, any reliance is to be placed upon the introspective testimony of the subjects, the conclusion must be drawn that only some of the subjects were fatigued. It is, therefore, evident that the second of the two main questions formulated on page 157 needs no discussion but must be answered with an emphatic negative. The fatigue of memorizing at a rapid repetition-rate is not so great as to cancel the time-saving effect of rapid repetition within the limits of a laboratory appointment lasting three quarters of an hour. Except for K. and for W. such fatigue as appears in a three-quarters-of-an-hour period is more evident in the case of the slowly repeated series than in the case of those rapidly repeated. Moreover, with W. and K. the fatigue (shown by the increase in the number of necessary repetitions) is far too small to counterbalance the gain in economy of time.

The final conclusion of the investigation is this: the problem is one which cannot be solved without much more experimental work. The results of those of our subjects who were certainly tired seem to show that rapid repetition is somewhat more fatiguing than slow, but before the statement can be substantiated it will be necessary to perform many experiments in which the periods of memorizing are long enough to tire the subjects. Such experimental conditions are hard to secure during the college year, for few of the available subjects are willing to be incapacitated for several hours from further academic work.

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A NOTE ON THE USE OF THE METHOD OF CONSTANTS IN EXPERIMENTS IN INTENSIVE SMELL DISCRIMINATION

By E. A. McC. Gamble

The experiments on which this note is based were made in the year 1913-1914 by Alice C. Forbes. The records numerical and introspective were completely destroyed in the Wellesley fire. Nevertheless, the results as remembered by the experimenter and by the writer of this note have a certain suggestive value, so that it seems worth while briefly to summarize them. The motive for the experiments was the desire to test the validity of a criticism made upon the method of the writer's effort to determine the applicability of Weber's law to smell.[1] At the suggestion of Zwaardemaker, the writer used Fechner's simple *method of just noticeable differences* which is really a rough form of the *method of stimulus production* and is, therefore, essentially "procedure with knowledge." In the course of the work she made a few experiments with the method of constants, for the purpose of determining its suitability, and definitely rejected it, because exhaustion seemed to make the second of the two compared stimuli almost invariably appear weaker than the first. After the publication of the work, the incompleteness of data unsubstantiated by the method of constants was pointed out by one of the critics of the paper.

The present experiments were made with the standard olfactometer of the ordinary form and with a fluid-mantle olfactometer of the form common in America, with which the subject breathes directly from an inhaling tube passing through the odorous cylinder. The substances used were, with the standard olfactometer, a combination of gum ammoniac and guttapercha and, in the case of the fluid-mantle olfactometer, vanillin. With one

---

[1] *The Applicability of Weber's Law to Smell.* American Journal of Psychology, (1898).

subject, who apparently has a vanillin defect, bees
in place of vanillin, of course, with the standard

The subjects included the writer, five subjects
eral experimental training but little experience in
and three untrained subjects.

The procedure each day included the following st
condition of the subject's nasal passages was tested
tion of the "breathing spots." (2) The stimulus li
termined on the basis of four trials with each nostri
ing for each nostril a stimulus of twice the limi
and taking for comparison a stimulus usually
stronger as many different determinations were ma
period of forty-five minutes as the intervals needed
for the cleaning of the apparatus allowed. In test
nostrils a compensating program was used. The s
told that the two stimuli would never be equal and
den to make equality judgments.

The results of these experiments certainly did not
the exhaustion produced by the first of the two stim
makes the use of the method of constants impossibl
ond of the two stimuli was wrongly judged strong
first in quite as many cases as those in which it
called weaker. Moreover, three of the partially trai
gave so large a percentage of right judgments as
stimulus difference supraliminal. Nevertheless, th
upon the experimenter and upon the writer the vivi
that the use of the method of constants is, in the c
subjects, undesirable. Three of the more painstak
had great difficulty in getting distinct impressions
tensity of the stimuli and were continually altering
of judging, sometimes attending to one phase of the
and sometimes to another. These same subjects we
asking whether their judgments were right or not,
considerable annoyance at the "vagueness" of the s
they were required to compare. In the case of sub
type, it would seem that training in smell discrimi
"procedure with knowledge" should be preliminary
of the method of constants.

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Children's Association Frequency Tables

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CHAPTER I

OBJECT

The primary object of the present investigation is to make a comparative study of the mental associations of children and adults. It is a study in group psychology, one group being that of children and the other that of adults. The study is made by means of association frequency tables.[1] We have compiled such tables from the responses of one thousand school children, of ages nine to twelve, to each of one hundred stimulus words. Since we used the same stimulus words as Kent and Rosanoff,[2] we have been able to take their adult frequency tables for comparison, and thus draw conclusions from a total of two hundred thousand cases of association.

A secondary object of our study, attained merely by the compilation of the children's association frequency tables, is to secure data which may serve as a standard in the studies of the mental associations of individual children. We believe that the responses of any child to the one hundred stimulus words, particularly when obtained several times and interpreted understandingly, afford one of the best pictures of his mental constitution that can be quickly obtained. It is in the picture, in the qualitative description, that we see the main value of the free association test,—not in any measurement it may give of the amount of intelligence. When regarded in this light, there is no reason why, in individual work, introspections should not be obtained, nor why association times should not be measured with the stop watch. It would seem, rather, to be imperative to obtain some introspective clues to the explanation of all exceptionally slow or very unusual associations. The frequency table is of value, in such individual study, as indicating what responses are most common, what most children do, and thereby affording a viewpoint from which to judge the individual child. Our various classifications of the data of the frequency tables may also be of value in this connection.

---

[1] What is meant by association frequency tables is generally known, but should perhaps be fully explained. A word, called the stimulus word, is pronounced to a subject who has been instructed to respond with the first word that the stimulus word brings into his mind. The word responded with is called the reaction word or the response. The same stimulus word is given, say, to a thousand individuals. These thousand individuals will not all respond with a different word, but with one of a comparatively small number of words, a hundred or so. Now a frequency table is one which shows just how often each of these hundred or so words occurred in the one thousand responses. Suppose one half of the thousand subjects responded with the same word, its frequency would be 500. Usually the greater part of the thousand responses will be one of a very small number of words. These will all have a high frequency. On the other hand there are always a number of words found to have been given only a few times. Those given only once, that is, those having a frequency of only one in the frequency tables, are called 'individual' associations.

[2] Kent, Grace Helen, and Rosanoff, A. J., 'A Study of Association in Insanity'. *Amer. J. of Insanity,* Vol. LXVII, 1910, 1 and 2.

It is true that attempts have been made to use the free association test as a measure of amount of intelligence. The test has had some success in this way and is probably of some value. A children's frequency table will prove invaluable to all such investigations that may be conducted in the future. We repeat, however, that the main value of the association test is not in telling us how much mind but what kind of a mind the child has. It is only as a qualitative test that it deserves the encomiums heaped upon it by so many authors, particularly Woodworth and Wells. The latter refer to the test as having achieved, and being likely to retain, a place "in the foremost rank among the methods of individual psychology,"[3] and assert that the results that may be obtained by the use of standard frequency tables give "perhaps the best objective correlate of temperament at present to hand."[4]

By our comparison of children and adults, we shall show that between the child and the adult there exist certain striking differences in mental make-up, differences with which we believe that the psychologist and the teacher of children should be thoroughly familiar. But we shall have nothing to say about how much more intelligent the adult is than the child.

---

[3] Woodworth, R. S., and Wells, F. L., 'Association Tests,' *Psychol. Monog.*, Vol. XIII, 1911. 57, p. 73.

[4] *Op. cit.*, p. 74.

The present study suggests a further use of our children's frequency tables, namely, its use for comparison with similar frequency tables obtained from children of different social status or race or of defective mentality.[5]

---

[5] Wreschner writes as follows: "Darum erweist sich aber das Experiment über Reproduktion und Assoziation als geeignete Unterlage einer angewandten Psychologie, wie kein anderes. Macht doch schon jetzt von ihm ausgiebigen Gebrauch die Sprachforschung, die Psychopathologie, die Jurisprudenz und die Pädagogik, und erkannten wir doch auf Schritt und Tritt, von welcher Tragweite es für die Psychologie der individuellen Differenzen ist. Voraussetzung all dieser praktischen Anwendungen ist aber eine möglichst genaue Kenntnis der Bedingungen, Eigenarten und Formen der normalen Reproduktion und Association." *Ztsch. f. Psychol. u. Physiol. d. Sinnes.*, Ergänzungsband, 3, 1907, p. 554.

CHAPTER II

PREVIOUS WORK

A knowledge of the methods and results of previous investigators of children's associations is indispensable to the proper interpretation and evaluation of the present data. Moreover, while the present work is intended primarily as a study in comparative group psychology, the present frequency tables may be employed by others in the study of individual differences. The success attained in this direction, however, will depend largely upon the user's knowledge of the psychology of association in children, as already established. It seems desirable, therefore, to give a brief résumé of preceding investigations, in so far as they bear upon the present study.

The first careful study of children's associations was published in 1898 by Ziehen.[1] Ziehen used 45 boys of ages 8 to 14. These he studied individually, chiefly by the oral method. The instructions to the subject, while similar to those used by later investigators, may have differed from those somewhat because of certain implications or suggestions. The child, upon having a word called out to him, had, as quickly as possible, to indicate that representation (Vorstellung) which immediately followed the representation awakened by the stimulus word.[2] It is evident that there is here a suggestion that the stimulus word called out to the child shall not immediately be followed by another word but that it shall first call up an image and that this first image shall then be followed by a second image, to be designated verbally. This suggestion was no doubt strengthened by the further questioning of the child, since, immediately upon giving his response, he was asked whether he had thought of a definite object[3]

---

[1] Ziehen, Th., *Sammlung von Abhandlungen aus dem Gebiete der pädagogischen Psychologie und Physiologie,* Vol. 1, 1899, 6, pp. 66.

[2] *Op. cit.,* p. 10.

[3] "Antwortete das Kind Z. B. auf "Frosch" mit "Laubfrosch," so frug ich, ob das Kind an einem bestimmten Frosch und Laubfrosch gedacht habe.

Ziehen formulated his main problem as follows: Does the association of ideas in the child as compared with the adult, show a preponderance or a lack of certain types of association? To answer this question, he compared the results obtained with children with those obtained from a "large number" of "analogous investigations" with adults. He obtained a very striking and important result. With adults, as the commonest case, he found that the stimulus word awakened a general idea (Allgemeinvorstellung) which in turn called up another general idea, designated by the response word. He estimates that this form of association occurred in 80 per cent of all the associations of his adults. With children, on the other hand, this association through general ideas was rare, though Ziehen says that it gradually increases in frequency with the age of the child. As by far the commonest case with children, he found that the stimulus word called up an individual or concrete idea, which called up another individual idea (Individualvorstellung). Ziehen says that while it is well known that a child does not employ the same range of general ideas in his thinking as does the adult, he was nevertheless astonished to discover to what extent the individual presentations predominate in the mind of the child. He concludes that in this respect the association of ideas in the child is different *toto coelo* from that of the adult.[4] Adults tend to think in terms of general ideas, children in terms of concrete representations.

Besides this fundamental difference between children and adults, Ziehen mentions several minor differences. Verbal associations occurred but seldom with children, apparently much less often than with adults, and were apt to take the form of word-completion, e.g., post,—card. Rhyme associations occurred very seldom, much more seldom than with adults. The same is true of associations of words commonly connected, e.g., hand,—foot; hope,—love.

---

und erhielt Z. B. zur Antwort: "ja an den Frosch, den Ring's (eine bekannte Familie) vor 3 Wochen gehabt haben." In anderen Fällen antwortete das Kind, es habe "an alle Frösche" oder "an keinen bestimmten" gedacht u. s. f." *op. cit.*, p. 11.

[4] *Op. cit.*, p. 32.

Ziehen was followed in his pioneer work by Meumann,[5] who studied the mental associations of over 800 school children, distributed in 19 classes, in the hope of obtaining criteria of degree of intelligence. He used 4 groups of 12 words each: first, concrete substantives; 2nd, verbs; 3rd, adjectives; 4th, abstract substantives. The words were read to a class of children by their teacher, and to each word the children had to write as a response the very first word that came into their head. The teacher gave a few examples first. With few exceptions, the children readily comprehended the aim of the experiment. Among the 8 year old children, however, there were a few who continually wrote words which stood in no connection with the stimulus words. Meumann presents hardly any of his actual data, and it is not clear just what method he used in arriving at his conclusions. The latter, however, are stated in great detail.

As characteristics of the associations of the less intelligent children, which serve to distinguish them from the more intelligent, Meumann mentions the following tendencies:— 1. The less intelligent more often misunderstand or misinterpret the stimulus word. 2. They more often fail to write down a response. In the case of abstract substantives, they may omit 60 to 70 per cent of the responses. 3. They give a greater number of senseless responses. The word written may be senseless or may stand in no apparent relation to the stimulus word. 4. Their responses show less mental work, or, as we might say, less thought. They take more often the form of mere word changes or rhymes, simple opposites, or words frequently named together, e.g., cat,—mouse. 5. Their responses are more dependent upon the connections established in their school exercises. 6. They are more apt to deviate from the concrete associations characteristic of children and to exhibit an apparent precocity by responding with general and abstract terms. The greater likelihood of opposites in the case of the less intelligent would also have to be included under this heading, since opposites are characteristic of adults. 7. As already noted by Ziehen, their responses are more apt to show perseveration, of which Meuman distinguishes three kinds. First, the response may consist in the repetition of a previous stimulus or response word. After its first occurrence, such a response stands in no apparent connection with the stimulus word. Second, and more commonly, a stimulus word starts a dominating chain of representations which then determine successive responses independently of the stimulus word. Third, the subject may hold to the same category of response, e.g., a strengthening adjective. This is only an index of unintelligence when the persistent category is not typical of the age in question.

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[5] Meumann, E., 'Intelligenzprüfungen an Kindern der Volkschule'; *Die experimentelle Pädagogik,* Vol. I, 1905, pp. 86-101.

It should be remembered that the data given in support of the above conclusions consist only in occasional illustrations. One of the conclusions which we believe stands in particular need of verification is that the less intelligent children are more apt to give logical opposites.[6] It should be noted, further, that the above-mentioned differences between the intelligent and unintelligent children are merely differences in the frequency with which certain types of responses are found in the case of groups of such children. It is not established that any of them are reliable indices of the intelligence of a given individual.

Meumann also mentions certain characteristics which he regards as distinguishing younger children from older ones. One might expect these characteristics to be the same as those distinguishing the less intelligent children from the more intelligent. Meumann himself suggests the following important proposition: the symptoms of relative stages in the development of the child's intelligence are at the same time symptoms of the relative intelligence of individuals of like age.[7] However, the characteristics which Meumann attributes to the more intelligent children, as compared with the less intelligent, are not identical with those which he attributes to the younger children as compared with the older. With the younger children, he says, the logical opposite hardly ever occurs, while, with the 13 and 14 year old children, it may constitute 90 or even 100 per cent of the responses.[8] The difference is particularly striking when adjectives are used as the stimulus word. The 8 and 9 year olds, in place of giving the logical opposite, seek mainly a substantive which the adjective given as stimulus word describes, e.g., white,—paper; black,—coal. On the other hand, as already noted, Meumann states that the less intelligent are more apt to give the logical opposite than the more intelligent.

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[6] *Op. cit.*, p. 91.

[7] *Op. cit.*, p. 101.

[8] *Op. cit.*, p. 99.

Another alleged exception to the parallel between age and intelligence has already been mentioned, namely, the tendency towards association of general ideas in the less intelligent children and in adults as contrasted with the use of concrete imagery in the case of the normal children.[9] In view of the importance of these alleged similarities between adults and the more unintelligent children, and the absence of supporting *data,* the matter should evidently be reinvestigated.

Winteler,[10] like Meumann, was interested in association as a possible means of diagnosis of intelligence. He obtained associations from 8 boys, all about 10 years of age, using a list of 40 stimulus words. The list included 25 nouns and 15 verbs and adjectives. Of these 8 boys, 3 were chosen, on the basis of their school work, as the most intelligent of their class, and 4, as the most unintelligent. The eighth boy was supposed to be of intermediate intelligence. Upon classifying the responses, according to their grammatical form, into nouns, adjectives, verbs and adverbs, he found that he could distinguish three reaction types.[11] These three types were about evenly represented, two of them by three boys each and the third by two. They showed no relation to the degree of intelligence. One type reacted to substantives mainly with adjectives, to adjectives with substantives, and to verbs with substantives; this is termed the perceptual (anschaulich) or describing type. Another type answered to substantives mainly with other substantives, to adjectives with other adjectives and to verbs with other verbs; this is designated the comparing or relating type. The third type is mixed. Those subjects responding largely with adjectives showed considerable perseveration, which Winteler explains as due to a closely limited stock of words.

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[9] *Op. cit.*, p. 93.

[10] Wintler, Jr., 'Experimentelle Beiträge zu einer Begabungslehre.' *Die experimentelle Pädagogik,* Vol. II, 1906, pp. 193-207.

[11] *Op. cit.*, p. 207.

Wreschner,[12] in the course of his extremely detailed study of association, obtained data on free association with two children, one of 3¾ and one of 5¾ years of age. He recorded their oral responses to something over 300 words, and compared them with the responses of twenty adults, with whom he used a list of words varying in number from 57 to 503. All the responses were classified by the aid of a classification schema of about forty headings, and a comparison then made of the percentages for adults and children under each heading.[13] Of course the number of children used, two, is entirely too small to give these percentages any considerable reliability. The investigation of Winteler, referred to immediately above, shows how greatly children may vary in the type of their associations, since, in a group of only eight boys, he distinguished three markedly different classes.

Without attempting to explain in full Wreschner's classification schema, we shall note the main similiarities and differences shown to exist between children and adults by his percentages.

Adults gave over twice as many logical associations, over one fourth of their associations being of this sort. This appears to be due to the greater frequency of association of opposites, similars and synonyms, and associations from effect to cause. Association of opposites is by far the commonest form of logical association amongst adults, and is about five times as frequent with the adults as with the two children. Another type of association which occurred more frequently with the adults than with the children is that which Wreschner terms verbal or speech completion. It includes three sub-types: word completion, e.g., snow,—ball; 'speech reminiscences,' e.g., fox,—goose; and a certain class of 'attributive unions,' e.g., mother,—dear. For all of these sub-types, the percentages were greater for the adults. Taken together, they constituted about a fourth of the adults' associations but only 7 per cent of the children's.

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[12] Arthur Wreschner, 'Die Reproduktion und Assoziation von Vorstellungen,' *Ztsch. f. Psychol. u. Physiol. d. Sinnes., Ergänzungsband*, 3, 1907, pp. 559.

[13] *Op. cit.*, pp. 285-294.

The children, on the other hand, favored two forms of predicative connections. One of these is the reaction-word-subject type, in which the reaction-word constitutes a subject of the stimulus-word, e.g., round,—circle. This form of reaction constituted about one fourth of the children's associations but less than one tenth of the adults'. The other predicative connection preferred by the children is the 'stimulus-word object,' in which the stimulus word is the object of the reaction-word, e.g., sand,—strew. This form of reaction constituted nearly a tenth of the children's associations but only one or two per cent of the adults'. The children also gave more frequently than adults associations classified as spatial and temporal localizations, e.g., windy,—outside; still,—night. These constituted about one tenth of the children's associations, but only about one thirtieth of the adults'. In all other respects than those mentioned no appreciable differences in association type existed between the adults and the children.

Saling[14] made some experiments on free association with a group of 34 school girls from 7 to 8 years old. The stimulus words were sixty in number and included ten of each of six varieties. The children had to think their reaction-words, and upon a signal from the experimenter to write them upon blanks. Saling compares the data thus obtained with results obtained on adults by Thumb and Marbe.[15] This comparison, made in the form of a table,[16] bears only on one point, namely, whether the most frequent response given to any stimulus word has a greater frequency with adults than with children. The table indicates that the most common response has a higher frequency, that is, constitutes a larger percentage of all the responses, in the case of adults than with children.

[14] Saling, Gertrude 'Associative Massenversuche,' *Ztsch. f. Psychol. u. Physiol. d. Sinnes.*, Vol. XLIX, 1908, pp. 238-253.

[15] Thumb and Marble, 'Experimentelle Untersuchungen über die Psychologischen Grundlagen der sprachlichen Analogiebildung,' Leipzig, 1901.

[16] *Op. cit.*, Tabelle I, p. 240.

This conclusion is clearly to a large extent due to the peculiar list of words used by Saling. It is noteworthy in the following respects: it is one-third composed of adverbs; it contains no verbs; it includes the names of the numerals one to ten; ten pronouns, and only ten nouns and ten adjectives; and, most striking of all, it is made up almost entirely, with the exception of numerals, of pairs of opposites or coordinates, e.g., father,—mother; brother,—sister; large,—small; old,—young; I,—you; he,—she; here,—there; everywhere,—nowhere; now,—never; this,—that. Both members of each such pairs are included in the list of stimulus words. Now the data presented in the present study will show very clearly that such pairs of words as these constitute the type of associations which, above all others, characterizes adults in contradistinction from children.[17] The most frequent response to such words with adults is nearly always the other member of the pair; and it is not surprising that the most frequent responses to such words show a higher frequency with adults than with children. The natural tendency of adults to respond by the opposite or the correlative would no doubt be strengthened by the constant occurrence of opposites in the list of stimulus words. It is clearly the peculiar character of Saling's list of stimulus words which accounts for the very high frequency of the most common or preferred responses. On the average, with adults, the frequency of the preferred response was 56 per cent. The Kent-Rosanoff adult frequency tables, on the other hand, show only one response of a frequency over 56 per cent, while they show an average frequency for the most common response of only 26 per cent.[18]

It is evident, from the above considerations, that we are not entitled to generalize Saling's conclusions. With other stimulus words, the frequency of the most favored response might not be as great in adults as in children. The result obtained would clearly depend upon what words were used as stimulus words.

Rusk[19] studied free association in 22 school boys, from 7½ to 14½ years of age. The stimulus words, thirty in number, were presented visually instead of orally. The instructions used were as follows: "A word will be shown, e.g., dog. When anything comes into the mind, either name it or say 'Now'; then tell as exactly as possible what passed in the mind. Take your own time, but answer immediately the first idea comes into your mind."[20] Among the conclusions reached may be mentioned the following:

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[17] See Chapter VI, p. 84-92.

[18] Cf. Chapter VII, p. 97-98.

[19] Rusk, Robert R., 'Mental Association in Children', *Brit. Journal of Psychol.*, Vol. III, 1909-1910, pp. 349-385.

"The degree of perseverance varies inversely with age and intelligence. The present investigation confirms the results of previous workers on this point.[21]

"The present investigation confirms the statement of Ziehen as to the astonishing definiteness and vividness of the child's imagery which has much the same characteristics as its perceptual experience, viz. vividness and definite spatial and temporal localization: it also supports the general view as to the great predominance of concrete visual imagery over other forms of imagery accompanying the thought processes of the child.

"Children who are best endowed with respect to the various forms of imagery do not, it would appear from the analysis of the introspection here undertaken, necessarily stand highest in school."[22]

Reinhold,[23] in 1910, published a children's association frequency table, based on data obtained from 300 school girls with 46 stimulus words. The girls ranged from 7 to 17 years of age, and were distributed in 10 successive classes, 30 in each class. The stimulus words were read to the class, and the children wrote down the first word that came to them. The number of different reaction words given by the 300 children to one stimulus word, was, on the average, 68.1. The average frequency of the most frequent response was about 26 per cent, but varied from 51.7 per cent (thunder,—lightning) to 10.0 per cent (play,—

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[20] *Op. cit.*, p. 359.

[21] Cf. Meumann, p. 6 above, conclusion no. 7.

[22] *Op. cit.*, p. 385.

[23] Reinhold, Ferdinand 'Beiträge zur Assoziationslehre anf Grund von Massenversuchen,' *Ztsch. f. Psychol. u. Physiol. d. Sinnes.*, Vol. LIV, 1910 pp. 183-214.

child(ren) and understand,—hear). The frequency with which no response was given varied from 1.7 per cent (for *tree*) to 22 per cent (for *understand*). Reinhold studied the variation with age in the percentage (of all the responses) constituted by the most frequent responses. He found no very reliable change in this percentage throughout the 10 different grades.[24] It has been mentioned above that Saling found the frequency of the most common responses to be definitely higher with adults than with children. The statement was made that this result would depend upon the words used, a statement that is verified by Reinhold's failure to find more than a mere suggestion of this tendency in comparing children varying in age from 7 up to 17. Reinhold's list of words, consisting mainly of unrelated nouns and verbs, was very different from that used by Saling.

Reinhold makes some interesting observations on the value of the free association test for the diagnosis of intelligence. Dividing each of his ten classes on the basis of school performance into halves, an upper and a lower, he finds no correlation between intelligence and the tendency to give sound associations, that is, associations where stimulus word and reaction word show similarity in sound. This finding contradicts one of Meumann's propositions.[25] Reinhold is, in general, skeptical of the value of the free association method for the diagnosis of individual ability. He points out that the reaction type is not always constant, but is easily and extensively modified by slight and unknowable influences.[26] For example, a school girl, who upon first testing gave 15 per cent of sound associations, upon second testing gave only 5 per cent, while another gave at first testing only 2 per cent, but upon retesting gave 75 per cent.

Goett[27] interested himself mainly in the use of free association tests for the diagnosis of mentally abnormal children, but, for the sake of comparison, studied normal children as well. He studied individually and by the oral method, using a list of 100 stimulus words, 52 children, between 8 and 14 years of age, of whom 24 were normal, 12 not quite normal, and 16 feeble minded, epileptic or hysterical. He did not ask for introspections as he thinks them unreliable when obtained from children.

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[24] *Op. cit.*, p. 184.

[25] See p. 6, no. 4.

[26] *Op. cit.*, pp. 213-214.

[27] Goett Theodor, 'Assoziationsversuche an Kindern,' *Ztsch. f. Kinderheilkunde*, Originale 1, 1911, pp. 241-345.

He gives first his results with normal children. He states that the reaction words themselves, regarded as such, and without respect to their relation to the stimulus words, have little interest. However, he notes the not infrequent presence in normal children of reactions by phrases, of faulty reactions, including both cases of no response and senseless response, and of perseveration, noting particularly the perseveration of prefixes, e.g., *un* and of suffixes, e.g., the German *ig*. As regards the relation of the responses to the stimulus words, Goett distinguishes between inner associations, or associations by conceptual relationship, e.g., ocean,—sea, horse,—animal, and outer associations, or associations by spatial and temporal contiguity, e.g. ocean,—ship, horse,—wagon.[28] Three-fourths of the children's reactions are found to be inner associations. Within the inner associations, he distinguishes three types, which he calls the predicative, the coordinating (including the contrasting) and the word compounding. The latter two types stand in a relation of opposition to the predicative. Like Jung, he defines the predicative associations as "all judgments, characteristics or activities that are in any manner related to the stimulus word as subject or object."[29] The following are illustrations of this type: glass,—brittle; father,—good; good,—father; tooth,—protruding; and sing,—song. This class constitutes 41 per cent of all the children's responses, or over half of the inner associations. For children under 12 years they constitute 50 per cent of all associations, while for children over 12 years they form only 33 per cent. A further very interesting finding is that the percentage of these predicative associations varies with the social class to which the children belong.[30] We reproduce the figures:

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[28] *Op. cit.*, p. 266.

[29] *Op. cit.*, p. 272.

[30] *Op. cit.*, p. 273.

	Children under 12	Children over 12
'Proletariate'	60%	40%
'Better circles'	30%	25%

With psychopathic children, Goett finds the free association test to be of decided diagnostic value. He mentions several features which he regards as characteristic of the associations of the feeble-minded. As compared with normal children, they are slower; they show more perseveration; they give a larger percentage of predicative reactions; they react more often with phrases instead of a single word, and persist in this form of reaction in spite of instructions to react with a single word.[31] All the features which Goett mentions as differentiating the feeble-minded from the normal, he also mentions as differentiating the younger children from the older. On the other hand, he finds that rhymes, word-completions, citations and simple contrasts very seldom occur with the feeble-minded. In only one of his cases, and that a case of moral rather than intellectual defect, did he find instances of association by contrast.[32] These findings are in opposition to those of Wimmer,[33] and are interesting in connection with the comment above regarding Meumann's conclusions.[34]

Rosanoff and Rosanoff[35] published a study in 1913 designed to answer the question, "At what age in childhood or in youth do the associational tendencies, as they are observed in normal adults, become fully developed, and what is the rate and manner of their development?"[36] Using the Kent-Rosanoff list of 100 words, they obtained the responses of 300 school children, twenty-five of each age from 4 to 15 inclusive.

"In making the tests the technique as originally presented could not in all cases be followed exactly; the best way seemed to be by asking the child, after his confidence had been gained and he had become composed, 'What does *table* make you think of?' Failing to obtain a response some other word would be selected: 'What does music make you think of?' or 'What does black make you think of?' In this way, eventually, a response was obtained, and it was then possible to proceed with the stimulus words in their proper order."

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[31] *Op. cit.*, p. 327.

[32] *Op. Cit.*, p. 324.

[33] Wimmer, A., 'Über Assoziationsuntersuchungen, besonders schwachsinniger Kinder,' *Monatsschr. f. Psych. u. Neurol.*, Vol. XXV. 1909. pp. 169-268.

[34] P. 7.

[35] Rosanoff, Isabel R., and Rosanoff, A. J., A Study of Association in Children,' *Psych. Rev.*, Vol. XX, 1913, 43-89.

[36] *Op. cit.*, p. 43.

"Many of the stimulus words often evoked either no response at all or only some such response as 'I don't know that' or 'Mamma never taught me that'; . . . Such instances were recorded as failures of reaction, but at the conclusion of every test the stimulus words to which no responses were obtained were given again with a view to reducing the number of failures of reaction in every case to a practical minimum."[37]

The association records obtained from the children were analyzed in accordance with the Kent-Rosanoff classification. Any response occurring only once in one of the Kent-Rosanoff frequency tables for adults is regarded as an individual adult association, unless it is a grammatical variant or derivative of some other word in the table, in which case it is called a 'doubtful' reaction. The percentage of individual reactions in the Kent-Rosanoff adult frequency tables is 6.8. This means that to each of their stimulus words, there occurred, excluding doubtful reactions on an average 68 responses with a frequency of only 1. Now the data obtained with children were classified according to the same rubrics, using the adult frequency tables as a standard.

Any reaction given by the children which did not occur at all in the adult frequency tables was classified as individual. This procedure is of value only in shedding light on the particular problem asked by Rosanoff and Rosanoff, as to when the associational tendencies of children become like those of adults. It will not determine whether children give more individual associations than adults. An individual association in the case of an adult means an association not given by other adults. That it may not be given by children does not make it an individual association. For example, the association, stomach,—organ, has a frequency of 81 in the Kent-Rosanoff table, and the association, hand,—foot, a frequency of 204. Neither of these associations occurs at all in our children's tables. Now for adults, these associations could not be classified as individual. Many such illustrations could be given.

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[37] *Op. cit.*, p. 44.

Similarly, an individual association in the case of a child should mean an association not given by other children, and should not be called individual merely because it does not occur with adults. We could give a long list of associations which have a frequency of 10 or over in our children's tables but which do not occur at all in the Kent-Rosanoff tables, and which would, consequently, have to be classed as individual associations if we followed the procedure of Rosanoff and Rosanoff. The following are a few illustrations, with the frequencies found in our children's tables: bread,—slice (13); boy,—trouser (16); moon, —face (13); street,—lamp (41); spider,-spin (10); beautiful, —doll (30); red,—lantern (13); working,—clothes (15); sour,—cream (52); loud,—cry (29); and carpet,—dirty, (35). Any procedure which classifies such children's associations as individual, merely because they are not found in the Kent-Rosanoff tables, even though it may be of aid in answering some particular question, is evidently far from satisfactory.

Even had Rosanoff and Rosanoff compiled children's frequency tables from their data, which they did not, it would have been impossible to reliably compare adults and children with respect to individual associations, because of the difference in the size of the groups. A frequency of one in a total of one thousand is a different thing from a frequency of one in a total of three hundred. The natural expectation would be that as the size of the group increased the absolute number of individual reactions would increase but that the percentage of such would decrease. This would be the natural result because of the principle noted by Saling that there is a tendency among normal persons to respond to any stimulus word by one or another of a fairly small group of words.[38] The impropriety of comparing percentages from association frequency tables based on widely different numbers was fully stated by Reinhold[39] and proved statistically by Dauber.[40]

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[38] *Op. cit.*, p. 14.

Passing from the consideration of methods to that of conclusions, we find that the Rosanoffs state as their main conclusion that, "as compared with adults, children, especially those under eleven years of age, give a larger number of doubtful and individual reactions and of failures of reaction, there being a corresponding reduction of common reactions."[41] They state further that, "All the characteristics by which test records of children differ from those of adults are most marked in the youngest children, grow less marked with advancing age, and become practically obliterated at the age of eleven years." Now the Rosanoffs have compared children and adults only with respect to the following characteristics: individual and doubtful reactions and failures of response. Their statement, then, to the effect that at the age of eleven years *all* characteristics of association in children are the same as in adults is evidently much too broad. We emphasize this point, because we believe that the characteristics in which the Rosanoffs have compared adults with children so far from being all-inclusive, are, in fact, comparatively unessential, technical[42] matters,—what Goett calls the 'by-products' of the association experiment.[43] We should say that the main comparison, and the only one which could really utilize all the data of frequency tables, was a comparison of the response words of children with those of the adults, to see whether these responses were the same and to what extent their frequency was the same. This the Rosanoffs have not attempted.

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[39] "Wenn man die Zahl der Versuchspersonen immer weiter vermehrt, tritt infolge der Beschränktheit des Sprachschatzes und auch schon infolge der Beschränktheit der Anzahl der bekannteren Wörter schliesslich der Fall ein, das es den neu hinzukommenden Versuchspersonen unmöglich oder wenigstens schwierig ist ein neues Reaktionswort zu nennen. Sie werden infolgedessen genötigt sein, um so mehr übereinstimmende Wörter zu nennen, je mehr die Zahl der Versuchspersonen wächst. Es ist daher nicht richtig, wie Wreschner es tut, die Zahl der bei einem Reizwort vorkommenden verschiedenen Reaktionswörter in Prozenten anzugeben." *Op. cit.*, p. 186.

[40] Dauber, Johann., 'Ueber bevorzugte Assoziationen und verwandte Phänomene,' *Ztsch. f. Psychol. u. Physiol. d. Sinnes.*, Vol. LIX, 1911, Table 8, p. 196.

[41] *Op. cit.*, p. 88.

[42] Whipple writes as follows: The author (Whipple) is inclined to believe that here, as in not a few other instances in which children differ from adults in psychological tests, what we are really bringing to light is an inability of the children to understand the instructions or disclination to follow them if they are understood."—'Manual of Mental and Physical Tests,' Part II, 2d ed., 1915, p. 62.

In conclusion, we shall mention three recent studies designed to show the value of free association experiments in the diagnosis of feeble-mindedness and the determination of mental age. These are the studies of Eastman and Rosanoff, Otis, and Römer.

Eastman and Rosanoff,[44] after a study of 253 subjects selected on the basis of backwardness in studies as rated by teachers, conclude that states of arrested mental development present certain fairly characteristic associational tendencies. These tendencies are characterized mainly by failures of reaction, non-specific reactions, e.g., person, man, article, nice, usé, etc., and certain types of individual reactions.[45]

Otis[46] studied 132 mentally defective children and 202 normal children by the Kent-Rosanoff association test. In the case of normal children, an unusual variation in procedure consisted in testing two children at the same time by the oral method. It is said, however, that the type of response was not affected by this method; that if a child tended to reply by associations of a certain type, he would continue to do so even though his neighbor were replying by associations of a different type. It is said, also, that the general result was not affected by the personality of the examiners, two of whom cooperated in giving the tests. Otis distinguishes five types of response,[47] as follows:—(I) Repetition of stimulus. If 50 per cent or more of a child's reactions are the repetition of the stimulus word, the child belongs to this type. (II) Non-logical. This means that words are given at random without connection with the stimulus word. (III) Sound reactions. The reaction word is connected by sound with the stimulus word. It may be either a word or neologism. (IV) Reaction consists of more than one word. This may be a noun with modifier, a phrase or a complete sentence. (V) Reaction one word, normal type. At least 50 per cent of these reactions must be found in the frequency tables of Kent and Rosanoff. Type I (repetition of stimulus word) is common in normal children of 4 or 5 years of age and in defectives of 2 to 6 years mental age. Type II (non-logical or incoherent) occurs in normal chilldren or 4 to 8 years of age, and in defectives from 3 to 5 years of age. It is commonest in normal children of years. Type III (sound reactions) appears sporadically. Type IV (reaction consists of more than one word) occurs in normal children from 4 to 8 years of age, and in defectives from 4 to 10 years of mental age. Type V (reaction one word, normal type) occurs in both normal and defectives as early as the age of 4 but is not established as the prevailing type much before the age of eight.[48]

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[43] Goett, Th., 'Associationsversuche an Kindern,' *Ztsch. f. Kinderheilkunde, Originale* 1, 1911, p. 258.

[44] Eastman, Frederic C., and Rosanoff, A. J., 'Association in Feeble-Minded and Delinquent Children,' *Amer. J. of Insanity,* Vol. LXIX, 1912, pp. 125-141.

[45] *Op. cit.,* p. 141.

[46] Otis, Margaret, 'A study of Association in Defectives,' *Journ. of Educ. Psychol.,* Vol. VI, 1915, pp. 271-288.

[47] *Op. cit.,* p. 275.

Our comment upon this work of Otis, as upon that of Rosanoff and Rosanoff, would be that it deals merely with by-products of the association test. From our viewpoint, the main thing she establishes, so far as the psychology of association is concerned, is that children under 8 are too young for the Kent-Rosanoff test. We would also criticize strongly the use of the Kent-Rosanoff adult tables for the determination of the normality of children's responses (see Type V).

Römer[49] is interested mainly in the use of the favorite, or most frequent, responses as a possible means of the diagnosis of feeble-mindedness. He obtained free association responses by the oral, individual method from 120 mentally retarded children. children of the Hilfschule of Würzburg, between the ages of 7.3

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[48] *Op. cit.*, p. 282.

[49] Römer, Fritz, 'Associationsversuche an geistig Zurüchgebliebenen Kindern,' *Forschritte d. Psychol. u. ihrer Anwendungen,* Vol. III, 1914, pp. 43-101.

and 15.6 years. For comparison, he obtained data by written class responses from 441 normal, school children from 7 to 14 years of age. His conclusions bear not only on the favorite responses, that is, those of highest frequency, but upon all responses of a frequency over one, which we may designate common responses. He finds that with retarded children the favorite responses are different than with normal children, and that, except in cases where the stimulus word is a numeral, their frequency is less. The frequency of the favorite responses increases with the chronological age of the normal children and with the mental age of the retarded children. It will be remembered that Reinhold did not find much regularity in the relation between the frequency of the favorite responses and age, but Römer thinks that it is definite enough to give value to free association as an intelligence test. He reckons, for each child, what percentage of his reactions consists of favorite responses. He then calculates for children of each age what percentage of favorite responses is exceeded by three fourths of them. This latter percentage he calls the minimal normal percentage of favorite reactions. He then observes that the great majority of his retarded children fall below the minimum for normal children of the same chronological age, but equal or exceed that of normal children of the same mental age.[50]

As regards the form of the associations of retarded children, Römer notes a very frequent occurrence of sound associations, of word completions, of the formation of new words, and of perseveration.[51]

In justice to the authors mentioned in the preceding review, it should be noted that reference has been made only to work which bears directly upon the problem of the present investigation, that is, upon the characteristics of free association in children. We have taken no account of work that has been done on controlled association, in which the response has to be of a certain category, nor have we discussed the somewhat conflicting findings on association time. On the latter point, however, a few words should be added, though it is unnecessary to attempt a detailed history.

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[50] *Op. Cit.*, pp. 100-101.

[51] *Op. Cit.*, p. 99.

By association time, is meant the time (usually measured by a stop watch in fifths of a second) elapsing from the pronouncing of the stimulus word until the occurrence of the subject's response. With unpracticed adults, the median association time is usually somewhere between 6 and 15 fifths of a second. With practice, this time tends to decrease towards a limit of 6 fifths of a second.[52] Now with children of 9 to 12 years of age, the association time is on the average longer than with adults, but at the same time very irregular. We have, also, noted enormous individual variations in children's association time. In spite of the fact that association time is unquestionably greater in children than adults, it has been hard to establish any reliable correlation in children between association time and age, mental or chronological.

In the case of adults, when any association requires considerably longer than the average association time of the individual, this association has unusual significance. It has been shown that such lengthened times are often due to the stimulus word being connected with strongly emotional complexes. Even in adults, however, there are other factors than emotional connections which tend to lengthen the free association time. On this point we may well quote from Wells.

"The free association time is exactly what its name implies, a measure of associative freedom. This involves a freedom of presentation, of selection, of expression. We obtain uniformly short association times in those individuals in whom all these processes are comparatively free. Where longer times are found, obstruction of some sort is indicated. . . . This is as far as the unsupported association time will carry one. It remains then to become acquainted with the nature of the obstruction. Where it is found, it must not be incontinently set down to emotional factors, but the roles of suppression, indecision, and the like, must be carefully compared and weighed by the best available means. Then only do the differences in association time assume their complete significance for the test, which is the most searching of all psychological experiments, and gives more coercively than all others, a paradigma of the subject's mental habits."[53]

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[52] Wells, F. L., 'Practice Effects in Free Association,' *Amer. J. of Psychol.*, Vol. XXII, 1911, p. 13.

There is little data on the causes of lengthened association times in children, but it seems probable that they are so very frequently connected with lack of familiarity with the stimulus word or with inability of the stimulus word to call up any associated word, that they have not the same value as with adults.

In conclusion, we may summarize briefly the present status of our knowledge of children's associations as compared with those of adults. Only two investigators have undertaken any systematic comparison of the association types of children with those of adults. These are Ziehen and Wreschner. Ziehen's main result, which is very important, consists in the determination that children make much greater use of concrete images and much less use of abstract ideas than do adults. Wreschner arrives at a number of interesting differences in association type between children and adults, but he used only two children, the oldest of whom was only 5¾ years of age.

In additions to the comparisons of Ziehen and Wreschner concerning association types, we have those of Saling and of Rosanoff and Rosanoff. Saling compared her results in children with those of Thumbe and Marbe and found that the most frequent response had a higher frequency with adults than with children. We have pointed out that this result was likely due to the peculiarities of the list of stimulus words used. Our own investigation emphatically fails to support the general validity of Saling's conclusion. Rosanoff and Rosanoff conclude that children give more individual associations than adults, but we have shown that their procedure was not capable of throwing any light on such a matter, but merely established that children's associations are different from those of adults. It does not tell us *how* they are different.

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[53] Wells, F. L., 'Some Properties of the Free Association Time,' *Psychol. Rev.*, Vol. XVIII, 1911, p. 23.

CHAPTER III

PROCEDURE

1. Oral and Written Responses.

The review of previous work in the preceding chapter has shown that various procedures have been used by different investigators. All these procedures agree, however, with the possible exception of Ziehen's and Rusk's, in that they call upon the subject to respond with the very first word called up by the stimulus word. The stimulus word has nearly always been given orally and the response either written or spoken, written when groups of children were used and spoken when the children were taken individually. In most of the more extensive investigations of children's associations, the children have been school children, who were taken in classes; and in such cases, the responses have been written. Written responses were used by Meumann, Saling and Reinhold. Römer used written responses with his normal children and oral responses with his mentally retarded children with whom he compared them.

So far as can be observed from the results reached, it matters little whether one uses the oral or written method. The main difference seems to be that with the written method cases of no response are more frequent, though the number of such obtained with the oral method depends greatly upon details of the procedure, such as the time allowed for a response and the patience, manner, suggestion and urging of the experimenter. The written method commends itself in statistical investigations because of the great saving in time and the greater uniformity of conditions. If a child hesitates, there is no extra waiting and no suggestive questioning,—no tendency to give him the word a second or a third time. We have, consequently, used the written method in obtaining data for the present frequency tables.

Since, however, the Kent-Rosanoff adults' tables were obtained by the individual oral method, we have checked up our results by compiling additional frequency tables for the first nine words from data obtained individually, by the oral method, from a thousand additional children. The results obtained by the oral method are given in full in our children's frequency tables, the frequencies obtained orally being distinguished from those obtained in writing by being in parentheses.

It does not require more than a cursory examination to see that in general the written and oral results run parallel. The same differences exist between adults and children whether we use the oral or the written data,—at least so far as the conclusions of the present monograph are concerned. One need not be surprised that in particular responses great discrepancies exist between the oral and written results. One must keep in mind the unreliability of the obtained frequencies. If one should compile another adult frequency table and compare it with that of Kent-Rosanoff, it would be very surprising if marked discrepancies were not found. Now it is very hard, without making certain questionable assumptions, to calculate the probable errors of the frequencies obtained in these tables. We have calculated, however, that less than 20 per cent of the discrepancies between our oral and written results can be reliably regarded as due to anything else than errors of sampling. On the whole, the oral and written results agree to a sufficient extent to indicate that the differences which are later pointed out to exist between children and adults are independent of details of the procedure,—that they represent real differences in mentality and not differences due to technique. To establish this proposition beyond dispute, however, we present in Chapter IX, detailed comparisons of the results obtained orally and in writing.

2. Instructions.

The instructions were essentially the same whether we used the oral or written method. In using the oral method, the instructions were given to the entire class. The children were then sent out one at a time into another room where, without further instructions, they were tested individually. It has been the experience of previous investigators that children need some illustration of what is wanted in the test. As the illustrations given may have a strong suggesting influence, it is important that they should be given very carefully and be accurately recorded. We wrote out our instructions beforehand. They were given as follows, an eraser first being taken from the chalk tray and held up before the class:

"If I were to ask you for the very first word that comes into your minds when I hold up this eraser, some of you would probably say, 'chalk',—'blackboard',—'write',—or 'school',—while others might think of the color, 'red', or 'blue'; or of the material of which it is made, as, 'felt', or 'wood'. Still others of you might remember that just before recess or noon you worked arithmetic on the blackboard, and that your work had to be erased before you could be dismissed,—and so to you, the sight of an eraser might suggest the word 'play',—'home',—'dinner',—or 'recess'.

"Now let us take another word, and I'll give you a quarter of a minute, by this stop watch, to think before raising your hands. What would you think of first if I said 'clock'? (Fifteen seconds allowed) Ready."

Instantly hands go up, and the responses are called for. The variety of responses serves well to illustrate what is wanted, and inspires confidence in the pupils. It also gives the experimenter a chance to correct any who reply with a phrase in place of a single word, or who merely repeat the stimulus word.

After this, instructions were continued, exactly as follows, for the written responses, and with the obviously necessary changes for the oral:

"What you are to do now, is this. I will give you a large number of words, but instead of telling me what they make you think of, I want you to write on some blanks I have here, the *very first* word that comes to your minds when I give you a certain word,—such as 'clock' that we just talked about."

Blanks, already ruled, are then passed, and the instructions for writing are given:

1. Write just one word on each blank.
2. That one word must be the very first word you think of.
3. Never write the word I give, for you will not have time.

4. If you do not think of anything when I give a word, leave blank the line on which it should have been written.

5. If uncertain how to spell a word, spell it by sound.

Just before beginning the experiment the following questions were asked, to be answered in chorus.

(1) Are you going to write the word I pronounce? (No.)

(2) How many words are you going to write on each blank? (One.)

(3) If you should think of two or three different words, which one would you write? (The first.)

3. Choice of Stimulus Words.

As we desired to compare our results with those of Kent and Rosanoff, we naturally used the same stimulus words. The data obtained by Rosanoff and Rosanoff had already shown, however, that some of the words were too hard for children. This was shown by the large number of failures to respond to some of the words. We accordingly added twenty words which seemed more appropriate for children, so that we worked with a list of 120 stimulus words. The words added were the following:—fun, school, ice, dog, friend, orange, mouse, finger, circle, kiss, bird, money, laugh, garden, ghost, flag, milk, pencil, stork, and candy. Of the 100 Kent and Rosanoff words, there were only ten, however, that gave over 20 per cent of failures to respond. We decided, therefore, to reject only those ten words and to use the results of only ten of our twenty new words in their place. Our frequency table, consequently, consists of one hundred words, ninety of which are identical with those of Kent and Rosanoff. Our comparisons of adults and children will be limited of course to these ninety words. The remaining ten Kent-Rosanoff words we regard as too unfamiliar to children to allow of satisfactory results.

The words rejected and substituted were the following:

Kent-Rosanoff Words Not Used	New Words Substituted
12. mutton	fun
13. comfort	school
19. command	candy
32. citizen	stork
45. trouble	garden
56. justice	flag
59. health	laugh
61. memory	milk
73. religion	ghost
76. bitter	friend

Of the ten Kent-Rosanoff words rejected, seven were found by Rosanoff and Rosanoff to give the largest number of failures of response, and the remaining three were also found by them to give failures comparatively often.[1] Since the words rejected by us were those which we found to give the largest number of failures of response, there is substantial agreement here between our results and those of Rosanoff and Rosanoff. In our children's frequency tables we have given the stimulus words the same numbers they have in the Kent-Rosanoff tables, and substituted our ten new words for theirs in the order indicated above.

4. Treatment of Failures of Response.

When it came to comparing children with adults, the presence in the case of the children, of a large group of failures of response with most of the stimulus words created something of a problem. In the Kent-Rosanoff adult tables, there are no cases of no response. It seemed improper to compare frequencies based on 1,000 adult responses with frequencies based on, say 900, children's responses. What we did, was to take enough additional responses to total one thousand actual responses, not including failures to respond. In order to have the material for this, we used 200 additional children, and, after arranging their blanks in haphazard order, counted down as far as necessary to get a number of responses equal to the number of failures of response with the stimulus word in question. We proceeded similarly with the oral data, fillling in failures of response from additional oral data. Our children's frequency tables are thus made up on the basis of one thousand actual responses.

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[1] *Psych. Rev.*, Vol. XX, 1913, Table III, p. 47.

These additional responses, substituted for the failures of response, we usually found to consist largely of the same words already obtained as responses, but they included always a number of new responses. That this filling-in procedure is not open to any material objection appears evident from the comparison we have made of the frequency tables obtained by the oral method, with which the number of failures of response was quite small, and those obtained by the written method. In general, then, it is probable that if the responses *had* been obtained from those children who did not respond, their responses would not differ strikingly from those of any other equal number of children.

The number of failures of response in one thousand children for each of the 100 stimulus words is given in the accompanying table. The data for the oral responses are given in italics.

Table Showing Number of Failures of Response to Each Stimulus Word

1.	Table	*(11)*	38	26.	Wish	122	51.	Stem	65	76.	Friend	174
2.	Dark	*(28)*	124	27.	River	18	52.	Lamp	22	77.	Hammer	34
3.	Music	*(16)*	22	28.	White	81	53.	Dream	108	78.	Thirsty	92
4.	Sickness	*(33)*	90	29.	Beautiful	39	54.	Yellow	49	79.	City	109
5.	Man	*(60)*	73	30.	Window	21	55.	Bread	38	80.	Square	184
6.	Deep	*(36)*	62	31.	Rough	127	56.	Flag	63	81.	Butter	79
7.	Soft	*(37)*	87	32.	Stork	82	57.	Boy	87	82.	Doctor	91
8.	Eating	*(11)*	61	33.	Foot	97	58.	Light	90	83.	Loud	187
9.	Mountain	*(13)*	46	34.	Spider	111	59.	Laugh	117	84.	Thief	77
10.	House		60	35.	Needle	37	60.	Bible	70	85.	Lion	79
11.	Black		102	36.	Red	115	61.	Milk	25	86.	Joy	107
12.	Fun		65	37.	Sleep	78	62.	Sheep	83	87.	Bed	31
13.	School		0	38.	Anger	109	63.	Bath	39	88.	Heavy	141
14.	Hand		102	39.	Carpet	66	64.	Cottage	23	89.	Tobacco	43
15.	Short		175	40.	Girl	120	65.	Swift	44	90.	Baby	92
16.	Fruit		44	41.	High	98	66.	Blue	58	91.	Moon	97
17.	Butterfly		112	42.	Working	118	67.	Hungry	103	92.	Scissors	29
18.	Smooth		161	43.	Sour	107	68.	Priest	114	93.	Quiet	114
19.	Candy		59	44.	Earth	97	69.	Ocean	38	94.	Green	66
20.	Chair		89	45.	Garden	41	70.	Head	126	95.	Salt	172
21	Sweet		109	46.	Soldier	39	71.	Stove	24	96.	Street	59
22.	Whistle		100	47.	Cabbage	57	72.	Song	89	97.	ping	117
23.	Woman		123	48.	Hard	175	73.	Ghost	149	98.	Cheese	65
24.	Cold		124	49.	Eagle	42	74.	Whiskey	83	99.	Blossom	59
25.	Slow		172	50.	Stomach	95	75.	Child	87	100.	Afraid	92

5. The Selection of the Children.

The children used in this investigation were all from 9 to 12 years of age, inclusive, and in either the 4th or 5th grade. Moreover, no children of 12 in the 4th grade were included. The children were therefore normal children. The number of children of each age composing the one thousand children used in the written work was as follows: 9 yrs., 236; 10 yrs., 327; 11 yrs., 293; 12 yrs., 144. The two hundred children whose responses were used to fill in cases of no response were distributed somewhat the same, as follows: 9 yrs., 40; 10 yrs., 71; 11 yrs., 56; 12 yrs., 33.

Of course, it would be desirable to have a frequency table for each different age, or for as many different ages as possible. We believe it unlikely, in view of the enormous labor of compiling such tables, that any individual would undertake to compile several of them. It was thought that the four ages in question might be fairly satisfactorily grouped together. We have, however, tabulated the results for the different ages separately. Data as regards the most frequently given responses are given in Chapter V. As will be seen, the agreement for the four ages is marked. It extends throughout the whole of the frequency tables. Compared with the differences between children and adults, the differences between 9 and 12 year old children are very slight.

There were several reasons which influenced us to use the ages of 9 to 12. It seemed to us that children of 8 or under were really too young to carry out the directions that go with the free association test. We were confirmed in this opinion by the study of Otis, which appeared while we were carrying on our work.[1] On the other hand, the results of Meumann and, to some extent, perhaps, those of Rosanoff and Rosanoff, suggested that, beginning at the age of 12 to 13, the associative tendencies of children begin rapidly to approach those of adults. Moreover, we had to consider that children in grades lower than the fourth have hardly sufficient control over the process of writing to be able to write their responses, and 9 years is the youngest age occurring with any considerable frequency in the fourth grade.

The children were all Minneapolis school children, and the tests were all given in the fall of 1914. Ten different schools were included, scattered in various sections of the city. In each school, four classes were used, the B 4th and A 4th, and the

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[1] See our account of 'Previous Work', Chapter II, p. 19-20.

B 5th and A 5th. The question might now arise whether results obtained in one city are as truly representative of the population in general as are the Kent-Rosanoff results obtained in various places in the East. We believe that they are fully as representative, because nearly all children of the ages we used are in school and therefore families of all classes and occupation are represented in about the right proportion. However, it may be well to keep in mind that these children are all *city* children and to be on the lookout for local influences. To the word river, we obtained the response Mississippi (which flows through Minneapolis) seventeen times and the name of no other river more than once. The Kent-Rosanoff results show just as much local color however, since to the word river they obtained the response Hudson thirty-three times, East, four, Mississippi, eight, and no other river more than once.

The children were of nearly all the nationalities commonly represented in the United States. They were asked to write the nationality of their parents upon the back of their blanks. The data obtained are shown in the following table:

NATIONALITIES

123	American
1	Armenian
6	Austrian
1	Austrian-American
1	Austrian-Servian
24	Bohemian
1	Bohemian-American
1	Bohemian-Norwegian
3	Canadian-American
1	Danish
2	Danish-German
3	Danish-Norwegian
1	Dutch
3	Dutch-American
3	Dutch-Swedish
33	English
7	English-American
1	English-Bohemian
1	English-Swedish
1	English-Swiss
5	Finn
30	French
4	French-American
1	French-Bohemian
1	French-Dutch
12	German-Swedish
1	Greek
67	Irish
17	Irish-American
2	Irish-Bohemian
1	Irish-Canadian
1	Irish-Chinese
13	Irish-English
1	Irish-German-English
1	Irish-Norwegian
1	Irish-Polish
3	Irish-Swiss
8	Italian
1	Italian-English
3	Jewish
68	Norwegian
9	Norwegian-American
3	Norwegian-English
1	Norwegian-Scotch-Irish
23	Norwegian-Swedish
46	Polish
1	Polish-Russian
3	Polish-Slavonian
34	Russian
10	Scotch

15	French-German
11	French-Irish
3	French-Norwegian
5	French-Scotch
1	French-Scotch-Irish
3	French-Swedish
90	German
20	German-American
4	German-Bohemian
1	German-Canadian
1	German-Dutch
1	German-Icelander
17	German-Irish
11	German-Norwegian
14	German-Polish
1	German-Roumanian
1	German-Russian
3	German-Scotch
11	German-Scotch-Irish
10	Scotch-American
6	Scotch-English
1	Scotch-German
17	Scotch-Irish
1	Scotch-Norwegian
2	Scotch-Swedish
3	Scotch-Welsh
19	Slavonian
114	Swedish
11	Swedish-American
1	Swedish-Danish
1	Swedish-French-German
1	Swedish-Irish
1	Swiss-American
8	Syrian
1	Welsh-American
1	Welsh-German
1	Welsh-Swedish

The thousand children given the oral tests were selected from the same ages and grades as those used in the written work, but from ten other schools. No record was kept of their nationality.

6. Classification and Comparison.

The question we have asked ourselves is, to what extent do children give the same responses as adults. The most complete answer to this question consists in the complete adults' and children's frequency tables. So far as possible, however, it is desirable to summarize the points of agreement and disagreement. To do this, it is necessary to study the tables from various points of view and to classify the results in various ways. The data of the frequency tables thus worked over are presented in Chapters VI to VIII.

In Chapter VI, we have attempted a somewhat elaborate comparison of children's and adults' associations according to association type. Chapter VII gives a comparison of the three most frequent responses of children and adults. In Chapter VIII, the children are compared with adults as regards the total number of responses and the number of individual responses.

The children's association frequency tables, which constitute our fundamental data, are given in Chapter IV, followed in Chapter V, by a study of the variation in the preferred reactions within the ages included in our study. In Chapter IX, we show that all the differences which we find to exist between children and adults hold whether we use the written or oral responses.

CHAPTER IV

CHILDREN'S FREQUENCY TABLES

The following tables show the frequency with which was given each of the responses to each of our 100 stimulus words. In the case of the first 9 stimulus words, for which responses were obtained orally as well as in writing, the frequencies for oral responses are given in parentheses. For all the other stimulus words, written responses alone were obtained. The total number of responses given for each stimulus word is one thousand, except in the case of the first 9 words, where it is two thousand, i.e., one thousand written, and one thousand oral responses.

For convenience in reference, we give a list of the stimulus words in alphabetical order. The order in which the list was read to the children is indicated by the numbers before the words, which correspond with the Kent-Rosanoff numbers, except in the 10 cases where we have substituted a new word in place of the Kent-Rosanoff word. Under the column headed 'Page' is given for each stimulus word the page on which may be found its frequency table.

STIMULUS WORDS

		PAGE
100.	Afraid	71
38.	Anger	50
90.	Baby	67
63.	Bath	58
29.	Beautiful	47
87.	Bed	66
60.	Bible	58
11.	Black	40
99.	Blossom	70
66.	Blue	59
57.	Boy	56
55.	Bread	56
81.	Butter	65
17.	Butterfly	42
47.	Cabbage	53
19.	Candy	43
39.	Carpet	50
20.	Chair	43
98.	Cheese	70
75.	Child	62
79.	City	64
24.	Cold	45
64.	Cottage	59
2.	Dark	34
6.	Deep	37
82.	Doctor	65
53.	Dream	55
49.	Eagle	54
44.	Earth	52
8.	Eating	38
56.	Flag	56
33.	Foot	48
76.	Friend	63
16.	Fruit	42
12.	Fun	41
45.	Garden	52
73.	Ghost	62
40.	Girl	50
94.	Green	68
77.	Hammer	63
14.	Hand	41
48.	Hard	53
70.	Head	61
88.	Heavy	67
41.	High	51
10.	House	40
67.	Hungry	60
86.	Joy	66
97.	King	70
52.	Lamp	55
59.	Laugh	57
58.	Light	57
85.	Lion	66
72.	Long	61
83.	Loud	65
5.	Man	36
61.	Milk	58
91.	Moon	68
9.	Mountain	39
3.	Music	35
35.	Needle	49
69.	Ocean	60
68.	Priest	60
93.	Quiet	68
36.	Red	49
27.	River	46
31.	Rough	47
95.	Salt	69
13.	School	41
92.	Scissors	68
62.	Sheep	58
15.	Short	42
4.	Sickness	35
37.	Sleep	49
25.	Slow	45
18.	Smooth	43
7.	Soft	38
46.	Soldier	53
43.	Sour	52
34.	Spider	48
80.	Square	64
51.	Stem	54
50.	Stomach	54
32.	Stork	48
71.	Stove	61
96.	Street	69
21.	Sweet	44
65.	Swift	59
1.	Table	34
84.	Thief	65
78.	Thirsty	64
89.	Tobacco	67
74.	Whiskey	62
22.	Whistle	44
28.	White	46
30.	Window	47
26.	Wish	46
23.	Woman	44
42.	Working	51
54.	Yellow	55

THE FREQUENCY TABLES

1. TABLE

1	(2)	able
0	(2)	arithmetic
1	(0)	ate
1	(0)	banana
1	(0)	bicycle
2	(1)	big
0	(2)	board
5	(0)	boards
5	(8)	book
5	(12)	books
0	(1)	boys
11	(3)	bread
8	(2)	breakfast
2	(0)	broken
1	(0)	butter
1	(0)	cable
1	(0)	cake
1	(0)	candy
1	(0)	cards
1	(0)	carpet
0	(1)	center-table
16	(30)	chair
8	(18)	chairs
0	(1)	children
0	(1)	class
1	(0)	clock
43	(30)	cloth
3	(0)	coffee
0	(1)	cold
1	(0)	come
0	(1)	cook
1	(0)	cooking
1	(0)	cover
7	(5)	cup
4	(2)	cups
4	(6)	desk
2	(2)	dining
0	(2)	dining-room
22	(28)	dinner
33	(11)	dish
126	(115)	dishes
1	(0)	daily
2	(3)	draw
0	(2)	drawer
358	(331)	eat
0	(1)	eatables
28	(33)	eating
4	(3)	eats
0	(1)	examples
3	(0)	feet
0	(1)	floor
0	(2)	flowers
17	(15)	food
1	(0)	foot
2	(2)	fork
4	(2)	forks
1	(0)	frame
0	(1)	furniture
0	(1)	get
0	(1)	hat
2	(0)	high
0	(13)	home
4	(12)	house
0	(1)	ice-cream
2	(0)	ink
1	(0)	is
0	(1)	kitchen-table
4	(3)	knife
10	(2)	knives
1	(0)	lady
2	(1)	lamp
1	(0)	lamps
4	(0)	large
8	(4)	leg
70	(56)	legs
0	(1)	light
0	(1)	lighting
0	(1)	long
0	(6)	lunch
0	(1)	magazine
1	(0)	map
2	(0)	marble
1	(0)	massive
2	(0)	meals
10	(0)	meat
1	(0)	men
0	(1)	multiply
0	(1)	multiplication
0	(1)	my
0	(1)	napkins
0	(1)	number
0	(1)	off
1	(0)	orange
2	(0)	oranges
1	(0)	paper
0	(3)	pen
1	(7)	pencil
0	(1)	pencils
1	(0)	people
1	(0)	pie
9	(7)	plate
12	(7)	plates
1	(0)	porch
1	(0)	potatoes
0	(3)	read
0	(3)	reading
0	(2)	room
6	(2)	round
2	(0)	salt
1	(0)	sat
0	(1)	saucers
0	(1)	school
1	(0)	seat
1	(0)	see
2	(2)	set
6	(15)	sit
0	(1)	sixes
0	(1)	sofa-pillow
0	(1)	something
0	(2)	spelling
12	(4)	spoon
4	(0)	spoons
1	(1)	stable
0	(1)	stand
0	(1)	store
0	(1)	study
0	(1)	studying
1	(0)	stuff
2	(1)	sugar
0	(1)	sugar-bowl
7	(4)	supper
10	(17)	table-cloth
1	(0)	tape
0	(1)	teacher
0	(1)	the
2	(0)	things
0	(2)	time-table
1	(3)	top
1	(0)	tumblers
2	(0)	turkey
1	(0)	twelves
0	(1)	twos
1	(0)	upon
0	(1)	use
0	(1)	using
0	(1)	varnish
1	(0)	vegetable
0	(1)	vegetables
1	(0)	whittle
21	(26)	wood
9	(0)	wooden
0	(4)	work
0	(1)	working
3	(44)	write
5	(25)	writing
1	(0)	written

2. DARK

49	(48)	afraid
1	(3)	alone
0	(1)	ark
0	(3)	asleep
0	(2)	awful
1	(0)	bark
0	(1)	bats
28	(16)	bed
1	(1)	bed-time
0	(2)	bird
80	(100)	black
1	(4)	blackboard
4	(3)	blue
1	(0)	board
4	(1)	book
3	(3)	brown
6	(0)	burglar
1	(0)	butter
0	(2)	camp
1	(2)	candle
1	(0)	can't
0	(1)	cave
0	(3)	cellar
1	(0)	chair
2	(1)	closet
1	(2)	dress
1	(0)	dungeon
1	(0)	dusk
1	(0)	eat
1	(1)	eraser
10	(5)	evening
0	(1)	face
1	(0)	fade
0	(2)	fear
0	(1)	fearful
3	(0)	fine
0	(1)	fire
0	(1)	flowers
0	(1)	forest
1	(0)	fright
0	(4)	frightened
3	(0)	gaslight
0	(1)	geography
0	(4)	ghost
0	(5)	ghosts
5	(5)	gloomy
0	(1)	go
0	(3)	goods
1	(1)	green
8	(3)	lantern
1	(0)	lark
7	(0)	late
38	(98)	light
2	(0)	lights
0	(1)	lonely
0	(1)	look
1	(1)	lost
7	(0)	man
1	(0)	marble
2	(0)	mark
3	(1)	match
1	(0)	mean
1	(0)	men
1	(3)	midnight
1	(0)	mice
10	(9)	moon
0	(1)	mouse
1	(0)	moving-picture
4	(0)	nice
421	(410)	night
0	(2)	night-time
5	(10)	no light
0	(2)	noises
1	(0)	not
1	(0)	sad
18	(18)	scared
0	(1)	scary
0	(2)	school
47	(21)	see
0	(1)	searchlight
0	(3)	shades
6	(0)	shadow
6	(0)	shady
0	(1)	shoe
0	(1)	shoes
0	(1)	sit
6	(0)	sky
6	(28)	sleep
0	(3)	sleeping
0	(1)	so
0	(1)	space
0	(1)	spark
3	(0)	star
1	(0)	stark
4	(0)	starlight
21	(12)	stars
2	(0)	startled
0	(1)	steps
2	(2)	storm
3	(0)	stumble
0	(1)	sugar

1	(1)	cloth
0	(1)	clothes
5	(2)	clouds
3	(0)	cloudy
4	(2)	cold
7	(17)	color
0	(2)	colors
0	(1)	complexion
4	(0)	corner
1	(0)	cough
1	(1)	curtain
1	(1)	curtains
3	(0)	dare
0	(1)	darkness
1	(0)	darkroom
1	(2)	day
0	(1)	death
0	(1)	den
4	(0)	die
1	(0)	dismal
0	(1)	grope
0	(1)	group
4	(2)	hair
0	(1)	hall
1	(0)	hark
0	(1)	hate
1	(0)	have
0	(1)	here
0	(1)	hide
1	(2)	home
8	(8)	house
1	(0)	I
1	(0)	inside
3	(0)	is
0	(4)	it
1	(0)	lady
15	(10)	lamp
1	(4)	lamps
6	(10)	not light
4	(0)	out
1	(0)	outside
2	(0)	pale
1	(0)	paper
0	(1)	park
0	(1)	people
0	(1)	pitch
0	(1)	pleasure
1	(0)	purple
1	(0)	rain
0	(1)	rainy
2	(0)	red
3	(0)	robber
0	(1)	robbery
29	(16)	room
0	(1)	rooms
0	(1)	supper
1	(1)	table
0	(2)	theirs
0	(1)	too
1	(0)	tree
0	(1)	trees
4	(0)	twilight
0	(1)	unlight
0	(1)	upset
0	(3)	very
3	(0)	walk
1	(0)	was
0	(1)	water
0	(1)	weather
0	(3)	white
0	(2)	wood
4	(3)	woods

3. MUSIC

1	(0)	angels
6	(0)	band
1	(0)	beat
0	(4)	beating
0	(2)	beats
11	(5)	beautiful
1	(0)	beauty
5	(48)	book
0	(16)	books
1	(0)	box
1	(0)	choir
0	(1)	clarinet
3	(0)	concert
7	(1)	dance
0	(2)	dancing
0	(1)	dinner
1	(3)	do
0	(1)	drawing
1	(0)	drum
0	(1)	easy
1	(0)	enjoy
0	(1)	eraser
1	(0)	excellent
4	(0)	fiddle
3	(2)	fine
0	(1)	finger
0	(3)	fun
2	(1)	girl
0	(1)	glad
33	(15)	good
1	(0)	grand
1	(0)	great
2	(2)	happy
0	(2)	hard
0	(1)	hardest
0	(1)	harmony
3	(0)	harp
0	(1)	hate
3	(1)	hear
1	(0)	hearing
1	(1)	here
1	(0)	high
0	(1)	history
0	(1)	home
0	(1)	Home Sweet Home
1	(0)	hook
1	(2)	I
10	(2)	instrument
5	(1)	joy
0	(1)	keys
0	(11)	learn
1	(2)	learning
17	(12)	lesson
4	(9)	lessons
17	(1)	like
0	(1)	line
6	(3)	listen
6	(2)	loud
1	(1)	love
0	(1)	lovely
1	(1)	melody
1	(0)	melt
0	(1)	merry
1	(0)	much
0	(1)	music-book
1	(1)	musician
29	(12)	nice
1	(0)	night
25	(5)	noise
1	(2)	note
10	(66)	notes
0	(2)	orchestra
19	(10)	organ
0	(1)	paid
0	(2)	paper
0	(4)	pencil
0	(1)	person
0	(1)	phonograph
198	(166)	piano
1	(3)	piece
1	(0)	pipe
0	(2)	pitch-pipe
81	(39)	play
2	(0)	played
1	(0)	player
1	(10)	playing
1	(0)	plays
1	(0)	pleasure
0	(1)	pointing
1	(1)	poor
2	(4)	practice
48	(22)	pretty
0	(1)	public
0	(2)	read
0	(5)	reading
0	(2)	record
0	(1)	rhythm
0	(1)	roll
1	(0)	room
1	(0)	rosy
1	(0)	sang
0	(2)	scale
0	(33)	school
1	(0)	serenade
0	(1)	sick
153	(236)	sing
23	(54)	singing
1	(0)	soft
0	(1)	soldier
50	(37)	song
1	(1)	song-book
16	(7)	songs
35	(0)	sound
1	(5)	sounds
0	(1)	spelling
0	(1)	staff
0	(6)	study
79	(19)	sweet
1	(0)	swell
0	(1)	take
0	(1)	tap
0	(1)	teach
2	(10)	teacher
1	(0)	ticket
5	(4)	time
2	(0)	tone
0	(1)	train
4	(0)	tune
1	(0)	victrola
25	(12)	violin
1	(10)	voice
0	(4)	we
0	(1)	whine
1	(0)	whistle
0	(2)	words
1	(2)	work
0	(3)	write
0	(3)	writing

4. SICKNESS

1	(0)	able
0	(1)	absent
5	(1)	ache
1	(0)	all right
2	(0)	alone
1	(0)	are
3	(0)	awful
4	(0)	baby
22	(17)	bad
1	(0)	duty
4	(8)	dying
4	(0)	earache
0	(2)	eating
2	(1)	faint
1	(0)	families
3	(0)	family
0	(1)	famine
1	(0)	kink
0	(1)	kitchen
1	(4)	lady
3	(2)	lay
0	(1)	like
1	(0)	lonesome
6	(1)	man
0	(1)	me
0	(1)	serious
0	(1)	sets
1	(0)	she
58	(65)	sick
1	(1)	sickly
0	(1)	sipped
1	(2)	sleep
0	(1)	small-pox
1	(0)	smother
0	(3)	sore throat

1	(0)	banana
105	(131)	bed
1	(0)	bedside
1	(0)	bicycle
1	(0)	bleeding
1	(0)	blind
5	(2)	boy
2	(0)	boys
0	(1)	brother
1	(0)	bum
0	(1)	careless
1	(0)	catch
0	(1)	chicken-pox
0	(3)	child
4	(0)	children
26	(18)	cold
1	(0)	consumption
7	(1)	cough
0	(1)	croup
3	(1)	crying
3	(2)	cure
0	(1)	dangerous
1	(0)	dark
9	(7)	dead
8	(44)	death
21	(14)	die
5	(0)	died
1	(0)	diet
13	(19)	diphtheria
0	(1)	disagreeable
24	(44)	disease
116	(116)	doctor
0	(1)	doctors
1	(0)	dread
0	(4)	dreary
2	(0)	drug
0	(1)	dull
1	(0)	fear
0	(1)	fearful
0	(1)	feeble
3	(1)	feel
0	(5)	feel bad
5	(0)	feeling
1	(0)	feet
1	(0)	felt
50	(36)	fever
1	(0)	flowers
1	(0)	friend
2	(1)	germs
2	(7)	girl
0	(1)	good
3	(0)	grippe
0	(1)	hard
1	(1)	has
1	(0)	have
0	(1)	he
3	(0)	head
26	(12)	headache
1	(0)	headway
6	(11)	health
1	(0)	healthy
1	(0)	hiccough
0	(13)	home
0	(2)	hope
10	(22)	hospital
0	(1)	hot
3	(3)	house
6	(6)	hurt
1	(4)	I
95	(94)	ill
5	(6)	illness
1	(0)	in
0	(1)	itches
1	(0)	kill
27	(40)	measles
35	(40)	medicine
1	(0)	miserable
1	(0)	money
4	(0)	mother
1	(0)	move
9	(3)	mumps
2	(0)	myself
1	(0)	night
1	(0)	not healthy
1	(2)	not well
7	(3)	nurse
1	(0)	nuts
14	(9)	pain
0	(1)	paint
0	(2)	pale
0	(1)	pall
3	(0)	patient
11	(7)	people
1	(4)	person
2	(0)	pills
1	(0)	play
1	(1)	pneumonia
4	(2)	poor
0	(1)	poorly
0	(1)	quarantine
0	(1)	quiet
4	(5)	sad
0	(4)	sadness
0	(1)	scared
42	(36)	scarlet-fever
2	(4)	school
1	(0)	school-ma'am
1	(0)	see
0	(6)	sorrow
1	(0)	sorry
1	(0)	spoon
1	(0)	stomach-trouble
1	(1)	suffer
4	(0)	suffering
0	(1)	summer-time
4	(2)	terrible
1	(0)	throat
6	(1)	tired
1	(0)	too bad
3	(4)	trouble
0	(1)	tuberculosis
0	(3)	typhoid-fever
1	(1)	unhappy
0	(1)	unhealthful
0	(4)	unhealthy
2	(2)	very
0	(1)	wan
1	(1)	was
2	(0)	water
0	(1)	we
34	(8)	weak
0	(2)	weather
20	(26)	well
2	(0)	white
8	(0)	whooping-cough
0	(2)	woman
1	(0)	women
3	(2)	you

5. MAN

3	(3)	adult
0	(1)	age
1	(0)	agent
1	(1)	all
3	(0)	American
0	(1)	an
1	(0)	animal
0	(1)	appearance
1	(0)	arm
0	(1)	arms
0	(1)	auto
1	(4)	bad
0	(1)	bald
1	(0)	bather
0	(2)	beg
0	(1)	beggar
1	(1)	being
0	(1)	best
57	(26)	big
3	(3)	body
0	(1)	book-binder
55	(29)	boy
1	(1)	boys
0	(3)	brave
0	(1)	bravery
2	(1)	burglar
8	(9)	business
0	(1)	can
7	(0)	cane
5	(2)	cap
0	(2)	carpenter
1	(0)	chap
0	(1)	child
3	(2)	fellow
0	(1)	flesh
0	(1)	food
2	(0)	foot
1	(0)	football
0	(2)	form
0	(1)	garden
4	(0)	gentle
4	(10)	gentleman
0	(2)	girl
0	(2)	goes
2	(0)	going
18	(7)	good
0	(2)	great
1	(2)	grow
5	(3)	grown
4	(10)	grown-up
5	(4)	hair
1	(3)	hand
3	(0)	hands
1	(0)	happy
0	(1)	hard
2	(1)	hard work
68	(82)	hat
7	(2)	he
9	(4)	head
0	(1)	height
1	(0)	help
3	(0)	helper
1	(2)	here
0	(1)	hidden
1	(0)	high
2	(0)	hire
1	(0)	loud
0	(1)	lumber
6	(2)	mad
8	(4)	male
4	(0)	mamma
3	(2)	manhood
0	(5)	married
3	(0)	marry
16	(11)	mean
19	(19)	men
0	(1)	miner
0	(1)	mister
0	(1)	Mr. Smith
5	(0)	money
0	(1)	muscles
1	(0)	my
3	(5)	necktie
0	(1)	negro
1	(2)	nice
3	(4)	office
4	(9)	old
1	(0)	one
1	(0)	out
0	(1)	overalls
2	(0)	overcoat
3	(0)	pa
1	(0)	pan
5	(6)	pants
7	(0)	papa
0	(1)	parents
0	(1)	pay
0	(1)	size
0	(1)	skillful
1	(0)	skin
1	(0)	slid
0	(2)	small
5	(0)	smoke
0	(2)	smokes
4	(0)	smoking
1	(0)	snowman
0	(1)	soldier
0	(1)	son
0	(1)	spade
0	(1)	steps
5	(1)	store
1	(0)	stout
1	(2)	street
1	(0)	strength
21	(23)	strong
0	(2)	suit
2	(5)	talk
32	(42)	tall
1	(0)	tan
0	(3)	teacher
0	(2)	the
1	(0)	there
1	(0)	thirty
5	(0)	tie
1	(0)	took
5	(4)	trousers
0	(1)	true
0	(1)	ugly
2	(0)	uncle
1	(0)	up

0	(1)	city
2	(0)	cloak
1	(0)	cloth
40	(42)	clothes
5	(2)	clothing
15	(28)	coat
1	(0)	cold
4	(2)	collar
1	(0)	creature
0	(1)	daddy
1	(0)	dark
0	(1)	dead
0	(1)	desk
0	(1)	doctor
0	(1)	dog
1	(1)	dress
1	(0)	drunk
0	(1)	dust
0	(1)	eat
0	(1)	Ed
0	(6)	eyes
1	(0)	excuse
14	(4)	face
0	(1)	family
0	(1)	fat
30	(19)	father
0	(2)	feet
3	(4)	home
0	(1)	homely
0	(2)	horse
2	(1)	house
6	(20)	human
0	(8)	human-being
0	(1)	hurt
7	(6)	husband
0	(1)	I
1	(0)	ill
2	(1)	janitor
0	(1)	kind
1	(0)	knitting
17	(18)	lady
3	(0)	lame
0	(1)	language
5	(4)	large
2	(2)	leg
1	(2)	legs
1	(0)	light
3	(0)	likes
2	(0)	little
0	(1)	live
2	(0)	living
0	(1)	long pants
8	(8)	people
1	(0)	pen
45	(38)	person
1	(0)	plan
1	(0)	play
0	(1)	plow
0	(1)	pocket
0	(1)	policeman
4	(2)	poor
1	(0)	potatoes
0	(3)	principal
3	(2)	ran
11	(0)	rich
2	(2)	robber
2	(0)	run
1	(0)	saloon
1	(3)	saw
1	(3)	school
0	(1)	see
1	(0)	sew
0	(5)	shirt
8	(6)	shoes
1	(0)	shoot
0	(1)	shooting
2	(1)	shop
0	(1)	shovel
0	(1)	show
7	(1)	sick
0	(1)	waiter
17	(27)	walk
3	(0)	walked
5	(9)	walking
3	(0)	walks
0	(2)	watch
1	(0)	went
0	(2)	whiskers
2	(0)	white
0	(1)	wife
0	(1)	wins
8	(40)	woman
0	(17)	women
168	(153)	work
2	(0)	worked
3	(2)	worker
11	(23)	working
0	(1)	working-man
0	(1)	workman
14	(9)	works
0	(1)	write
1	(0)	yes
0	(1)	you
5	(2)	young
1	(0)	your
1	(1)	youth

6. DEEP

1	(0)	a
5	(2)	afraid
1	(0)	are
2	(1)	awful
0	(1)	angle-worm
1	(0)	ball
5	(0)	barn
1	(0)	barrel
1	(0)	beautiful
9	(5)	big
0	(1)	billow
8	(6)	black
0	(4)	blue
4	(0)	bottom
0	(1)	bottomless
0	(3)	breath
0	(1)	breathing
1	(0)	bridge
1	(0)	bury
1	(0)	can't
0	(1)	cave
5	(3)	cellar
1	(0)	cloud
0	(1)	cold
0	(1)	color
3	(1)	cover
1	(0)	creek
0	(2)	creep
1	(3)	cup
1	(1)	cut
0	(1)	dangerous
12	(33)	dark
0	(1)	darkness
0	(5)	depth
12	(5)	dig
0	(1)	digging
4	(5)	dirt
1	(0)	dish
7	(4)	ditch
0	(2)	dive
47	(43)	down
0	(1)	dreary
9	(8)	drown
4	(2)	drowned
1	(2)	drowning
2	(4)	dug
0	(1)	dungeon
0	(1)	earth
0	(1)	erase
17	(15)	fall
3	(0)	fall in
0	(1)	falling
25	(41)	far
0	(1)	fearful
1	(1)	feet
5	(0)	fell
1	(0)	fire
2	(1)	fish
1	(0)	fishing
0	(3)	forest
0	(1)	frightened
0	(1)	gone
1	(0)	good
0	(1)	grass
2	(1)	grave
3	(0)	groan
21	(23)	ground
0	(1)	grown
3	(1)	hard
1	(0)	haunt
1	(0)	heap
1	(1)	heart
2	(0)	heavy
3	(0)	height
4	(19)	high
0	(1)	hill
257	(244)	hole
2	(0)	holes
8	(5	hollow
1	(0)	in
1	(0)	inside
3	(0)	is
2	(3)	it
1	(1)	jump
0	(1)	ladder
9	(9)	lake
0	(1)	land
7	(9)	large
1	(0)	leap
1	(0)	length
2	(0)	like
1	(0)	limp
1	(0)	lion
12	(14)	long
2	(1)	lost
4	(0)	love
35	(52)	low
1	(0)	man
1	(0)	mat
1	(0)	mine
0	(1)	moderate
0	(3)	mud
0	(1)	my
0	(3)	narrow
1	(0)	nice
15	(14)	ocean
0	(1)	outside
1	(0)	peak
0	(1)	peep
0	(6)	pit
2	(1)	play
4	(0)	pond
1	(0)	race
1	(0)	reap
0	(2)	red
36	(30)	river
2	(1)	rocks
0	(1)	room
3	(0)	round
1	(0)	run
1	(0)	salt
3	(1)	sand
1	(0)	saw
2	(0)	scared
14	(27)	sea
1	(0)	seeds
1	(0)	serious
0	(3)	sewer
6	(16)	shallow
1	(3)	shovel
0	(1)	ship
8	(1)	sink
0	(1)	sky
1	(0)	sled
3	(2)	sleep
0	(1)	snakes
10	(1)	snow
1	(0)	so
0	(1)	soft
0	(1)	soil
1	(0)	some
0	(1)	sore
0	(1)	sorrow
7	(2)	steep
2	(0)	stream
6	(3)	swim
0	(1)	table
1	(0)	thick
0	(1)	thin
0	(1)	think
1	(3)	thought
2	(0)	through
0	(1)	underground
0	(1)	understanding
0	(1)	up
1	(0)	vase
4	(0)	very
3	(0)	voice
145	(162)	water
1	(1)	way
87	(76)	well
0	(2)	wet
5	(0)	wide
1	(0)	wood
11	(6)	woods
0	(2)	work

0	(1)	baker
5	(6)	banana
0	(3)	bananas
1	(0)	beans
3	(0)	beating
2	(2)	bite
0	(1)	biting
178	(152)	bread
10	(20)	breakfast
2	(3)	butter
18	(9)	cake
16	(9)	candy
2	(4)	chair
1	(0)	cheese
0	(8)	chew
7	(3)	chewing
3	(1)	chicken
1	(0)	clean
2	(1)	coffee
1	(3)	cook
4	(2)	cookies
0	(1)	cooking
1	(0)	cracker
3	(0)	cup
0	(1)	delicious
0	(2)	digest
0	(1)	dining
42	(44)	dinner
1	(5)	dish
3	(9)	dishes
1	(1)	done
0	(1)	don't
6	(3)	drink
2	(6)	drinking
1	(0)	drinks
51	(58)	eat
3	(2)	eaten
1	(0)	eating-house
3	(0)	eggs
0	(1)	finish
2	(1)	fish
54	(103)	food
11	(15)	fork
1	(0)	forks
1	(0)	fresh
4	(4)	fruit
5	(5)	full
1	(3)	girl
1	(0)	girls
39	(47)	good
3	(0)	goodies
2	(1)	grapes
1	(0)	he
3	(2)	healthy
1	(0)	heart
2	(0)	hearty
1	(0)	help
0	(1)	high
6	(8)	home
0	(3)	house
8	(3)	hot
43	(37)	hungry
1	(2)	I
2	(0)	ice
13	(3)	ice-cream
0	(1)	is
1	(0)	it
2	(0)	kitchen
8	(8)	knife
0	(2)	knives
1	(0)	let's
0	(2)	like
2	(2)	live
1	(2)	lots
0	(1)	lumber
4	(11)	lunch
1	(0)	melon
1	(0)	mice
5	(2)	milk
0	(2)	mother
0	(1)	mouse
4	(7)	mouth
0	(1)	muskmelon
3	(0)	napkin
2	(2)	nice
0	(1)	noon
0	(1)	noon-time
1	(0)	not
2	(2)	oatmeal
4	(3)	orange
0	(4)	oranges
3	(0)	peanuts
0	(1)	people
0	(2)	person
2	(0)	pickles
1	(8)	pie
3	(0)	pies
3	(7)	plate
3	(0)	plates
0	(1)	play
0	(1)	polite
3	(0)	potato
25	(23)	potatoes
1	(0)	prayer
2	(0)	pudding
1	(0)	pumpkin
1	(0)	rabbit
1	(0)	raisins
1	(0)	rice
0	(1)	room
1	(0)	salt
1	(0)	salting
6	(18)	spoon
0	(1)	starving
0	(1)	steak
1	(1)	stealing
3	(1)	stomach
2	(0)	store
5	(0)	stove
0	(1)	strong
3	(2)	sugar
1	(0)	suit
29	(30)	supper
5	(6)	swallow
1	(0)	sweet
0	(1)	swell
108	(113)	table
2	(0)	take
1	(0)	taken
3	(0)	taste
3	(2)	tasting
3	(0)	teeth
6	(0)	Thanksgiving
1	(0)	there
1	(0)	thing
1	(0)	things
0	(1)	through
0	(1)	tomatoes
1	(0)	too much
6	(0)	turkey
0	(9)	vegetables
0	(4)	victuals
1	(0)	waffles
6	(0)	warm
1	(0)	was
0	(1)	washing
0	(1)	water
0	(2)	we
0	(1)	you

9. MOUNTAIN

0	(1)	air
0	(1)	Alaska
11	(3)	Alps
1	(0)	bad
7	(3)	bear
1	(0)	beautiful
13	(26)	big
1	(0)	black
0	(1)	Blue Mts.
1	(0)	bowlder
1	(0)	breaks
0	(2)	brick
1	(0)	burrow
1	(0)	cabin
1	(0)	California
0	(1)	Canada
0	(1)	cattle
0	(1)	cave
1	(0)	caves
0	(1)	cement
1	(7)	cliff
29	(50)	climb
18	(12)	climbing
13	(0)	cold
0	(2)	cool
0	(2)	country
1	(0)	cowboy
3	(0)	crater
0	(1)	crevice
1	(0)	dark
1	(0)	deer
1	(0)	fell
0	(1)	flowers
0	(1)	forest
1	(5)	fountain
1	(0)	frosted
8	(0)	frozen
2	(0)	fun
2	(3)	geography
4	(1)	glazier
1	(1)	go
0	(2)	goat
3	(0)	goats
15	(6)	gold
0	(1)	granite
2	(6)	grass
1	(2)	ground
1	(1)	hard
15	(0)	height
390	(432)	high
1	(0)	higher
1	(0)	highest
4	(0)	highland
91	(104)	hill
6	(12)	hills
0	(3)	hilly
0	(6)	horse
0	(2)	house
1	(0)	I
10	(0)	ice
2	(0)	iceberg
8	(0)	icy
2	(2)	lion
0	(1)	live
1	(0)	man
1	(0)	men
3	(0)	mile
1	(0)	mine
0	(1)	mineral
0	(1)	mines
0	(1)	mining
0	(1)	Montana
1	(2)	mount
0	(3)	Mt. Blanc
1	(0)	mounted
0	(1)	mule
0	(1)	on
0	(1)	Osakis
0	(1)	outside
37	(13)	peak
13	(4)	peaks
0	(2)	Pike's Peak
1	(0)	place
1	(0)	plain
0	(1)	plateaus
0	(1)	rain
0	(2)	range
2	(1)	river
0	(1)	rivers
1	(0)	road
15	(17)	rock
34	(47)	rocks
0	(2)	Sheep
3	(0)	silver
2	(0)	skis
2	(0)	sledding
2	(0)	slide
1	(0)	slippery
0	(1)	smoke
61	(43)	snow
3	(0)	snowy
0	(1)	soft
1	(0)	springs
3	(3)	squirrel
32	(24)	steep
12	(0)	stone
1	(5)	stones
0	(1)	summit
0	(3)	Switzerland
0	(2)	tall
0	(1)	ten
0	(1)	the
1	(1)	there
0	(1)	things
0	(5)	top
0	(2)	train
1	(2)	travel
0	(1)	traveling
1	(3)	tree
1	(16)	trees
1	(0)	trolley-car
15	(0)	up

[illegible]

[illegible] (8 valley
11 (14) volcano
[illegible] walk
[illegible] (0 was
[illegible] Washington
[illegible] (4) water
[illegible] (0) west
[illegible] (4 woods
[illegible] (0) work

10. [illegible]

[illegible]

[illegible] pretty

[illegible]

[illegible] school
[illegible] schoolhouse
[illegible]
[illegible] shingles
[illegible] sleep
[illegible] small
4 smoke
[illegible] stairs

[illegible] stay
[illegible] step
3 steps
6 stone
8 stove
[illegible] storm

19 table
1 top
3 trees
1 two

2 village

1 wall-paper
1 ward
62 warm
3 warmth
3 white
1 wide
11 window
12 windows
40 wood
1 wooden
5 work

3 yard
1 yellow

11. BLACK

2 [illegible]

1 [illegible]
1 [illegible]
1 [illegible]
26 blackboard
4 bone
42 board
1 boards
1 book
1 boy
1 burnt

7 cat
4 chalk
4 charcoal
4 chimney
2 clock
2 closed
9 cloth
5 clothes
8 coal
10 coat
1 coke
104 color
1 colors
4 coon

1 crane
2 crayons
1 crepe

[illegible] dark
1 darkness
2 danger
1 dangerous
1 dead
5 dirt
42 dirty
11 dog
1 drab
63 dress

1 face
5 feathers
1 flat
3 floor
1 funny

1 globe
3 gloomy
5 goods
1 green
1 gray

3 hair
3 hands
4 hat
1 hatbox
1 heavy
4 hole
4 horse
4 house

2 I
31 ink
1 inquire
2 iron
2 is

1 jacket

1 kitten

3 lead pencil
1 lever

1 mack
1 men
1 moon
1 mourn
3 mourning

5 mud

1 nap
1 negro
1 nice
15 night

1 orange

32 paint
1 painted
3 pants
1 paper
7 pen
13 pencil

1 racer
1 rain
3 red
11 ribbon

1 sheep
1 shine
1 shirt
1 shoe
9 shoes
9 skirt

4 sky
6 smoke
1 soil
3 soot
1 sorrow
1 south
8 stove
1 stoves
1 suit

1 thread

2 veil
3 very

3 waist
2 wear
1 were
27 white
3 woods
1 wool
1 write

3 yarn

12. FUN

2 bad
35 ball
7 baseball
5 basketball
1 box
4 boy
10 boys
2 build
1 bun
1 butter

1 can
1 cap
4 cheery
2 child
13 children
1 clock
1 cookie

3 dark
1 delight
2 delightful
4 digging
2 dirt
1 doll
9 dolls
3 doors

1 down
1 drowned

2 eat
5 eating
1 enjoy
2 enjoying

2 fall
2 fell
3 fight
1 finger
9 fishing
1 food
15 football
3 frolic
3 full
5 funny

12 game
38 games
1 gay
1 girl
2 girls
4 glad
9 good
4 goodtime

1 ground
4 gun

1 had
16 happy
4 happiness
17 have
11 hide & seek
4 hockey
2 hop
3 hurt

1 I
1 it

3 jokes
1 joking
6 jolly
29 joy
6 jump

18 laugh
2 laughed
3 laughing
1 light
5 like
5 lots

3 lunch

6 marbles
2 money
1 much

8 nice
2 noise

2 outdoors
1 outside

394 play
34 playing
4 pleasure

3 race
2 ran
1 rat
2 read
3 recess
3 rope
46 run
1 running

4 school
1 see

1 sew
2 shovel
2 show
4 skate
1 skates
11 skating
3 sled
2 slide
5 snow
6 snowball
6 snowballs
2 snowfight
4 sport
7 swimming

22 tag
2 time
2 toy
1 toys

1 very

2 walk
1 water
1 well
1 window

13. SCHOOL

39 arithmetic

1 bad
2 bell
14 blackboard
24 book
81 books
3 boy
14 boys
1 brick
6 building

1 ceiling
1 chair
5 chalk
101 children
2 classes
3 clock
1 crayon

2 day
5 days

31 desk
20 desks
6 door

1 education
5 eraser

1 fool
3 fun

6 girls
29 go
7 going
3 grounds

1 happy
2 Holmes
1 home
2 hours
14 house

3 language

18 late
93 learn
5 learning
2 lesson
14 lessons
1 like

1 map
3 mates
3 morning
6 music

5 paper
17 pencil
1 pens
1 people
7 play
4 playmate
1 pool
6 pupil

28 read

18 reading
1 reads
13 recess
1 rest
1 roof
16 room
4 rooms
2 ruler
1 run

6 scholar
7 schoolmate
1 schoolroom
10 seat
3 seats
3 Sheridan
1 smart
17 spelling
3 spool
1 starts
1 steps
2 studies

38 study

2 tardy
9 teach
44 teacher
6 teaching
1 telephone
1 theirs
1 think
8 time
1 trees
2 Tuttle

1 wait
3 went
1 whole
1 word
68 work
2 working
15 write
24 writing

3 yard

14. HAND

44 arm
1 ax

3 band
2 beckon
12 big
2 black
2 blisters
4 body
4 bone
5 bones
1 book
1 breakfast
6 broad
3 broke
3 broken
3 brown
1 busy
1 button
1 by

14 dirty
1 doing
2 draw
1 dress

5 eat
4 eating
3 elbow
1 every
1 eyes

1 face
1 fast
2 fat
2 feel
1 felt
69 finger
5 fingernail
3 fingernails
130 fingers
1 first

3 have
1 head
1 heart
1 help
3 her
1 his
17 hold
1 hook
3 hurt
3 hurts

1 iron

1 kind
1 kiss
1 knife

1 land
2 large
6 left
2 leg

6 nail
3 nails
1 nice

1 o'clock
1 one

1 pain
1 paint
6 palm
1 pen
7 pencil
1 penny
1 pick
1 picture
1 piece
1 pores
7 pretty
1 pulling

3 raise

1 scratch
1 sweat

1 take
3 take hold
1 them
1 there
5 throw
3 touch
3 two

33 use
1 used
12 useful
1 using

7 veins

1 was
5 wash
1 watch

4 carry
2 catch
8 chapped
23 clean
65 clock
1 cloth
7 cold
1 comfort
1 command
3 cook
1 crawl
5 cut

5 five
4 flesh

1 girl
4 gloves
1 go
1 goes

1 handed
1 handle
1 handout
1 hang

2 lift
3 little
1 long

1 man
5 meat
4 mitten
7 move
2 moving
2 muscle
2 music
1 my

2 reach
18 right
11 ring
7 rough

1 sand
1 sew
6 shake
16 skin
1 skirt
11 small
10 soft
8 sore

13 white
1 wood
113 work
6 worked
6 works
4 wrist
52 write
1 writes
9 writing
2 wrote

1 your
5 yours

15. SHORT

1 are
1 around

12 baby
1 bad
1 banana
8 big
5 block
5 board
1 boat
20 boy
1 brief
1 broad
1 broke

7 cake
1 chalk
3 child
1 close
4 clothes
1 coat
1 court
1 cut

1 Dan
4 day
1 descent
8 distance
1 dog
38 dress

1 easy

1 eating

11 fat
2 feet
13 finger
15 fingers
3 flowers
1 fly
1 fort
1 fringe

14 girl
2 good

8 hair
5 hand
1 he
1 hook
1 hours
3 house

4 inch
1 inches
1 is

1 Japanese
1 jiffy

1 ladder
1 ladies
1 lads
23 lady

1 large
5 leg
4 legs
3 length
6 lesson
5 letters
1 life
2 line
157 little
1 lock
54 long
1 lort
5 low

43 man
1 men
1 mice
1 minute
1 mouse
1 my

3 name
1 narrow
1 neck
1 nice
3 night
1 not

1 papa
6 pants
1 paper
46 pencil

1 people
4 person
1 piece
1 pin
1 port

1 quick

2 reach
3 ribbon
1 right
6 rope
1 round
1 ruler
1 run

1 size
7 skirt
6 sleeve
214 small
1 smooth
1 sock
14 stick
1 still
1 stocking
1 stone
4 stop
1 stork
5 story
7 stout
2 strap
15 string

2 stub
15 stubby
2 stump
1 stumpy

12 tall
3 thin
1 thing
9 time
5 tiny
1 tree
1 try
1 tubby

1 very

2 waist
15 walk
1 was
5 way
1 wide
3 winter
2 woman
1 women
1 wood
1 word
1 write

2 you
1 young

16. FRUIT

131 apple
174 apples

52 banana
44 bananas
1 belong
5 berries
3 big
1 bread
1 butt

4 cake
5 California
2 can
1 carrots
1 cone

1 delicacy

1 delicious

153 eat
2 eatable
25 eating
1 eatness
1 eggs

3 food
2 fresh

3 garden
89 good
1 goodies
3 grape
29 grapes
3 green
4 grows

2 have
1 high
1 hot
2 hungry

1 jam
1 juice
7 juicy

1 kind

2 like
2 look
2 love

1 mute
1 nectar
12 nice

54 orange
45 oranges

8 peach
14 peaches
9 pear
7 pears
4 plums

1 quiet

3 red
4 ripe
2 rotten

2 salad
2 sauce
1 sauces

9 seeds
2 spoiled
3 strawberries
20 sweet

1 taste
1 there
1 thing
7 tree
4 trees

10 vegetables
3 vegetables

1 yesterday

17. BUTTERFLY

8 air
18 animal
2 ant

2 beast
1 beating

1 capture
5 catch
8 caterpillar
3 caught
2 chase
10 cocoon

4 field
4 flew
41 flies
19 flower
7 flowers
179 fly

7 insects
1 it

5 little
1 look

5 saw
3 seen
1 setting
1 seven
3 silk
5 small

17 beautiful
6 beauty
4 bee
9 big
57 bird
1 bread
1 bring
6 brown
14 bug
5 bugs
54 butter

1 cage

3 color
3 colored
1 colors
16 creature

1 dandelion
1 dark
1 dragon

1 eat
1 eats

1 fast

1 flyer
18 flying

4 garden
3 golden
1 green

1 head
1 high
5 honey
1 hurt

66 insect

1 moth

2 net
7 nice

1 picture
4 play
1 pet
4 powder
89 pretty

7 red
1 rich

5 soft
1 soul
3 spring
16 summer
1 sunbeam
1 sunshine

1 web
13 white
23 wing
114 wings
6 worm

47 yellow

18. SMOOTH

1 ain't
4 apple

6 bed
1 bench
15 blackboard
43 board
1 book
1 box
1 bright
1 butter

3 candy
4 carpet
4 cat
4 chair
1 clean
1 clear
25 cloth
1 clothes
1 coat
1 color
4 cotton
2 cozy
1 crooked
2 cup

33 desk
4 dress

4 easy
1 egg
3 eraser
70 even

3 face
3 feathers
3 feels
2 fine
29 flat
20 floor
1 flowers
11 fur

48 glass
2 glossy
3 good
2 grease
13 ground

4 hair
3 hand
7 hands
10 hard

39 ice
1 in
1 iron
4 ironed
4 it

1 lake
2 land
4 leather
55 level
1 leveled
3 light
2 line
1 lumps

1 mind
1 mold
3 molded

2 neat
68 nice
1 no

33 paper
5 pavement
5 pencil

3 picture
2 pillow
4 plain
4 plane
1 play
1 potatoes
1 pretty

2 quilts

1 right
3 road
10 rock
35 rough
4 round
1 rugged

1 sand
1 salt
1 shining
7 shiny
1 sight
5 silk
1 silky
4 slick
2 slide
19 slippery

1 smoothed
3 smoother
1 smooths
6 snow
132 soft
1 soothe
2 stone
39 straight

16 table
3 tablecloth
1 talk
1 tender
1 thin
1 tone

1 use
1 useful

2 varnish
8 velvet
3 very

5 wall
5 water
4 window
5 wood

19. CANDY

2 ate

2 bad
2 bought
12 box
1 boy
1 bring
3 brown
2 burn
7 buy

2 candy-man
3 caramels
1 cat
25 chocolate
5 chocolates
1 confectionery
1 cookies
2 cooks

3 coughdrops
2 cream

2 dandy
2 dirty
1 dog

181 eat
3 eatables
1 eaten
13 eating
2 eats

1 fruit
7 fudge

1 gone
149 good
3 goodies

2 goods
2 goody
2 grocers
14 gum

2 had
11 hard
2 hate
5 have
2 honey

3 ice cream

2 lemon
4 licorice
18 like
3 love

8 make

4 marshmallow
5 money

7 nice
7 nickel
2 nut
2 nuts

1 pastry
15 peanut
4 penny
8 peppermint
2 person
3 pink
2 please

2 rich
1 round

5 soft
7 stick
9 sticky
15 store
14 suck
39 sugar
297 sweet
1 sweetmeats
13 sweets

3 teeth
2 treat

1 wax
3 white

1 yellow

20. CHAIR

21 arm
6 arms

17 back
1 bare
1 bear
2 bed
14 big
6 board
1 book

1 crooked

5 desk
1 doll's
1 down

2 eat
1 eating
9 easy

2 have
8 heavy
9 high
10 house

1 I
1 iron

1 king

6 nice

1 on

1 pair
1 piece

5 rest
3 rock
3 rocker

17 sitting
4 small
6 soft
3 stand
8 stool
5 straight
3 strong
1 supper

29 table

2 box
1 boy
5 broke
10 broken
2 brown

2 cloth
1 color
3 comfort

2 fall
1 feel
1 feet
7 furniture

3 good
3 grandpa

3 hair

7 large
5 leather
18 leg
26 legs
1 level
1 look
3 low

1 nap

13 rocking

9 sat
2 school
131 seat
38 set
1 setting
430 sit
2 sits

2 use
2 useful

1 white
34 wood
5 wooden

1 yellow
3 your

21. SWEET

45 apple
21 apples

5 baby
1 banana
8 bananas
1 beautiful
1 beloved
1 biscuit
1 bite
1 blossom
5 butter
5 bread

10 cake
146 candy
3 cherries
18 chocolate
1 coffee
1 cold

6 cookies
1 cream
1 cute

1 dear
1 delicate
4 delicious
4 doll
4 drink

13 eat
1 eating

1 flavor
5 flower
4 flowers
1 freeze
3 frosting
4 fruit

10 girl
213 good
4 goodies

1 he
23 honey

11 ice cream
1 it

4 jelly
8 juicy

5 lady
1 like
1 lovable
3 love
3 lovely

2 meat
1 meet

17 milk

37 nice

7 orange
26 oranges

3 peas
3 perfume
5 pickle
6 pie
1 play
1 potatoes
16 pretty

3 rich
3 rose
4 roses

1 sauce

1 sick
1 slow
7 smell
1 something
1 song
1 sorrow
1 sounds
23 sour
1 stew
178 sugar
1 sugary
1 sweetpea
4 syrup

23 taste

1 very
1 voice

1 wood

22. WHISTLE

1 aloud
2 arrested

1 bad
1 beckoned
12 bird
12 blew
189 blow
2 blowing
1 blown
2 blows
79 boy
24 boys
1 breath
1 bristle
4 bullet

14 call
4 calling
5 can
1 canary
3 can't
1 castle
5 come

3 dinner
2 dog

3 engine

3 fast
2 finger
4 fingers
19 fire
1 frolic
4 fun

4 girl
1 goat
3 good
1 got
1 green

7 happy
5 hard
1 has
1 have
5 hear
3 hearing
1 help
1 her
1 high
1 him
1 hole
10 holler

9 horn

1 Jim
1 Joy

1 kind

2 lady
1 let's
1 like
1 likes
6 lips
3 listen
1 long
71 loud
4 low

2 make
6 man
1 mean
4 merry
1 missle
5 morning
16 mouth
14 music

11 name

5 nice
185 noise
6 noisy
6 noon
4 nose
1 note

1 people
1 pipe
1 plow
7 police
1 pretty

1 ring
1 ristle
2 round
3 run

2 scared
2 sharp
2 shout
11 shrill
6 sing
2 singing
1 sings
1 somebody

9 song
18 sound
1 squeaking
6 steam
1 story
1 supper

1 thistle
2 time
1 tin
1 tone
4 toot
21 train
11 tune

2 whisper
2 whistler
7 willow
22 wind
9 wood
3 wooden
1 work

1 Yankee Doodle

23. WOMAN

4 adult
1 arm

3 babies
5 baby
6 bake
4 big
1 blanket
5 busy

1 can
1 child
13 children

1 face
2 fashions
4 fat
1 feather
9 female
7 furs

17 girl
4 gloves
2 going
12 good
1 grin

3 kiss

1 laces
13 ladies
243 lady
3 large
4 laugh
1 legs
1 likeness
6 little
1 living
1 look
1 looking

1 one

6 people
21 person
1 plush
1 poor
12 pretty
1 prize

6 run

1 say
2 sewing

1 straw hat
3 sweep
12 sweet

1 tall
1 talk
1 tarts
6 teacher

1 use
1 useful

2 waist

3 cleans
1 cloth
9 clothes
1 club
2 coat
19 cook
3 cooking
5 cooks
1 crone

1 dead
1 dies
5 dishes
5 dishwashing
96 dress
17 dresses

4 eyes

7 hair
5 hands
44 hat
1 hats
2 head
1 hire
3 home
1 hose
7 house
2 housekeeper
1 housework

1 it

1 Jennie

3 kind

1 maid
4 mamma
17 man
4 marry
5 married
1 me
2 mean
1 men
1 mend
1 Miss
53 mother

2 neat
10 nice

9 old

4 sews
1 shawl
4 she
1 shoe
3 shoes
1 shopping
4 short
2 silk
1 sings
1 singing
13 skirt
7 skirts
1 slim
1 slow
5 small
1 straight

9 walk
1 walking
2 warm
17 wash
4 washed
5 washing
2 washwoman
1 way
1 weak
1 wealthy
1 went
1 widow
18 women
42 work
9 works

24. COLD

5 air
2 awful

1 baby
2 bad
1 beng
1 below
1 bird
2 biting
6 bitter
10 black
1 blackboard
25 blow
3 bold
3 boy
1 breath
4 breeze
1 bundle
2 burn
3 buttermilk

1 came
1 chair
1 chase
3 child
5 chill
1 chilly
1 close

10 coal
17 coat
1 colder
13 cool
37 cough
1 coughs
1 cream

1 damp
25 day
1 do
5 doctor
3 dog
1 dreary

6 ears
4 evening

5 feel
6 feet
1 felt
1 fever
9 fingers
17 fire
68 freeze
40 freezing
5 frost
1 frosty

16 froze
9 frozen
1 fuel
2 fun

1 hand
13 hands
1 hard
1 head
1 heat
1 hold
12 hot
11 house
4 hunger

84 ice
3 ice-cream
6 icy
3 illness
1 is
1 it

1 Jack Frost

1 meat
1 medicine
4 mitten
1 mold

8 nose
1 numb

1 old
1 one
4 out
9 outdoors
3 outside
13 overcoat

1 pneumonia
1 pole

1 rain
1 recent
1 red
4 room

1 severe
1 she
15 shiver
5 shivering
1 shivery
4 sick
4 skates
6 sleet
4 sliding
1 sneeze

62 snow
1 soup
1 stony
5 stove

3 thermometer
1 thing
1 think
6 today
1 too

8 very

25 warm
1 warming
1 was
5 water
34 weather
7 whooping cough
36 wind
5 windy
103 winter

8 zero

25. SLOW

9 auto
1 automobile
4 awful

2 babies
1 baby
2 bad
3 balky
9 behind
2 bicycle
3 blow
2 book
6 boy

1 can't
1 cat
4 child
2 children
6 clock
4 come
1 cooled
2 cow
2 crawl

3 dinner
5 dog
3 donkey
1 don't
7 drag

2 dress

9 early
13 easy
3 eating
5 elephant
1 engine

65 fast
4 faster
3 feeble
4 feet

19 girl
3 girls
2 glow
18 go
3 goes
4 good

2 happy
1 he
3 heavy
29 horse
2 horses
20 hurry

10 lag
1 lagging

2 lame
25 late
1 lazily
138 lazy
5 lessons
14 long

20 man
2 me
5 molasses
4 move
2 moving
2 music

2 near
1 night
8 not
2 not quick

1 oh
2 old
14 oxen

3 people
1 pig
4 poke
35 poky

4 quick

3 reading
3 reads
7 run

2 said
10 school
3 sew
3 short
1 show
1 slack
5 sleepy
8 slowly
2 snail
1 snake
2 snow
1 soft
2 something
1 song
1 stew
2 still
16 stop
3 stopping
1 stole
1 stupid
1 sum
5 swift

5 talking
3 tedious

9 time
4 tired
4 tiresome
2 too
1 top
1 tops
2 tortoise
3 train
22 turtle

7 very

21 wagon
1 wait
1 wake
1 waken
107 walk
12 walking
2 walks
4 was
1 way
31 work
1 worker
2 working
1 worry
4 write
1 writing

7 you

26. WISH

3 anything
2 apple
9 ask
2 asked
5 asks
1 at home

4 ball
3 bicycle
3 birthday
3 boat
85 bone
3 book
4 boy

5 cake
41 candy
3 cap
3 cat
15 Christmas
5 come
1 cone
6 could

4 desire
4 did
3 dish
3 do
16 dog
46 doll

3 dollar
11 dress

1 eat

3 fairies
64 fairy
2 father
6 fish
2 flowers
6 for
2 fun
8 furs

5 game
18 get
7 gift
1 gladly
1 go
1 going
3 gold
19 good
2 grand
14 grant
4 guess

13 had
3 happiness
3 happy
3 hard

1 harm
25 have
2 her
5 home
10 hope
16 horse
2 horses
3 house

6 I
4 ice
1 ill
2 it

2 king

10 like
3 look
1 lot
17 luck

1 mad
3 man
1 me
4 merry
1 mish
12 money
1 monkey

6 nice

1 nickel

1 offer

1 park
1 pen
17 pony
4 present
2 prince

1 rainbow
5 ribbon
9 rich

2 sad
5 Santa Claus
1 sane
2 school
2 she
1 show
12 skates
4 sled
36 something
5 star
2 storybook
3 suit

1 tall
4 telling
1 the

5 thing
2 things
37 think
3 thought
2 thousand
1 time
2 toy
6 toys
6 train
43 true

2 wagon
1 wait
5 wand
99 want
3 wanted
4 watch
1 water
6 well
2 what
1 which
7 wishbone
2 wished
3 wishing
4 witch
1 with
1 worked

2 you

27. RIVER

4 bath
4 bathing
14 big
37 boat
1 branches
3 bridge
1 broad
7 brook

4 canoe
1 cold
5 current

44 deep
2 delta
2 dirty
1 dive

11 drown
11 drowned
9 drowning

1 fall
4 fast
34 fish
8 fishing
1 float
16 flow
5 flowing
33 flows
1 freeze
2 frog
2 froze
6 frozen

2 go over

3 high

13 ice
1 icy

42 lake
1 large
1 lime
5 long
3 low

17 Mississippi
1 muddy

1 near

3 ocean

1 ran
3 rapid
1 riding
1 rivulet
1 road
4 rock
3 row
5 run
13 running
16 runs

3 sail
1 saw
1 silver
4 skate
1 sliver
3 slow

4 small
2 soft
30 stream
6 swift
72 swim
7 swimming

1 that

433 water
2 wave
3 waves
1 wear
10 wide
1 width

1 Yangzte

28. WHITE

1 air
1 angel
6 apron

1 baby
2 bath tub
5 beautiful
1 billow
1 bird
28 black
1 blackboard
1 blue
1 board
1 brave
3 bread
16 bright

4 cat
3 chair
7 chalk
97 clean
4 clear
1 cloak

3 collar
116 color
1 colored
2 cotton
2 curtain

1 dainty
1 dark
3 dead
1 dike
3 dirty
1 do
4 dog
1 draw
149 dress
1 duck

5 face
1 fast
1 fine
8 flag
1 flight
1 flour

8 goods
1 gown

2 hair
2 hands
1 hard
1 hat
3 horse
19 house
1 hurt

1 ice
1 ice cream

1 jacket
1 jam

1 kitten

1 lace
125 light
2 lovely

1 net
10 nice
1 nightgown

1 old

6 paint
6 pale
1 pants
54 paper
1 people
1 pictures
1 pig
1 pigeon
1 pillow
1 plain
24 pretty
4 pure

1 rabbit
1 red
1 rib
14 ribbon

1 sewing
1 sheep
7 sheet
1 ship
1 shoes
1 sick
2 sky
65 snow
1 soft
2 still
2 stocking
1 swan
1 sweep

1 table
6 tablecloth
1 thread
1 tight
1 too
1 towels

1 veil
1 very

61 cloth
5 clothes
1 cloud
1 clouds
3 coat
1 coin

4 flowers

2 ghost
1 gleam
1 goat
1 good

1 man
2 mice
7 milk
1 my

1 name

1 right
1 rims

1 sail
1 screen
1 see

6 waist
1 walls
1 wear

2 yellow

29. BEAUTIFUL

1 are

10 baby
1 be
19 beauty
1 bed
3 belle
5 bird
1 birds
1 bright
7 butterfly
1 bury

1 careful
1 carriage
12 cat
3 child
1 class
2 clean
5 coat
14 color
5 cute

3 day
1 diamonds
30 doll

6 dog
28 dress

4 face
1 fair
1 feet
3 fine
1 flag
6 flower
37 flowers
1 forest
1 fountain

4 garden
27 girl
1 glorious
3 good
1 gorgeous
2 graceful
10 grand
3 great
1 green

7 hair
1 have
13 handsome

7 hat
4 homely
9 horse
7 house

1 is

1 jewelry

38 lady
4 lake
3 laugh
2 like
3 lion
1 look
3 looking
3 looks
4 love
1 loving
8 lovely

1 magnificent
2 man
1 mother
1 mountain
1 muff

2 name
169 nice
1 niceful

2 palace
4 park
1 petticoat
15 picture
3 pictures
1 plant
5 pony
2 powder
280 pretty
3 prince
4 princess

3 ribbon
1 rich
3 ring
2 river
9 rose
2 roses

2 satin
2 scenery

4 she
1 shine
9 silk
3 skin
3 stars
2 store
7 sun
3 sunset
3 sweet
2 swell

1 thing
3 tree

3 very

2 wagon
13 woman
5 women
12 wonderful
4 woods
3 wreath

9 you

30. WINDOW

8 air

1 ball
8 big
1 blows
1 board
13 break
1 breeze
1 brick
37 broke
23 broken

1 church
1 class
6 clean
1 close
21 cold
1 cooler
1 comfort
7 curtain
1 curtains

3 dirty
2 door
1 down

1 fall
6 frame
1 fresh
1 frost
1 frosty
1 froze
1 frozen

1 girl
1 glance
421 glass
1 grass

1 hall
12 house

1 I

1 icicle
1 invisible
1 it

2 large
47 light
3 little
116 look
2 looked
2 looking
8 lookout

24 open
6 out
4 outdoors

62 pane
1 pillow
1 plate

1 rattle

5 room
1 run

1 sale
1 sash
1 sat
2 school
1 screen
36 see
1 seeing
6 shade
2 shines
1 shiny
1 shot
5 shut
9 sill
2 stained
1 stare
1 straight
1 streetcar
1 storm

4 sun

1 take
1 through
1 toys
4 tree
5 trees

9 up

1 varnish

12 wash
1 white
5 wide
2 wind
1 windmill
2 windows
1 wood

31. ROUGH

2 angry
2 are

16 bad
1 bear
2 beard
4 big
27 board
1 book
89 boy
37 boys
2 broom
2 bump
23 bumps
61 bumpy

2 decay
3 dirt
3 dog
1 doll
2 door
1 dress

1 enemy

1 fall
6 fight
2 fighting
1 file
2 files
1 flat
15 floor

2 horrid
2 horse
1 humpy
8 hurt
1 hurtful

9 ice
1 iceberg
2 irregular

2 jagged
2 jerky

1 knot

2 language

1 pain
12 paper
3 place
2 plain
5 plaster
25 play
3 playing
1 pleasant
2 poor
1 pump

1 rat
1 railway
1 red
1 ribs
2 right

8 sidewalk
2 skin
2 slivers
2 small
35 smooth
1 soft
1 stand
1 sticker
11 stone
4 stones
1 stove
2 stumps

2 table
1 tear
1 torn

1 cake
1 candy
4 careless
1 carpet
1 chair
1 chap
5 chapped
1 Charles
7 child
6 cloth
2 clothes
1 clumsy
4 coarse
1 coat
1 cocoa
1 come
1 cough
1 crooked
1 cut-glass

2 football
2 frog
3 fur
1 fuzzy

1 gentle
1 girl
1 glass
1 goody
1 grass
14 ground
1 gruff

13 hand
15 hands
144 hard
1 hill
3 hit
4 hitting

1 leather
1 line
1 logs
2 lumpy

11 man
71 mean
1 meat
1 men
3 mountain
5 mountains
1 mouse

1 nasty
3 naughty
1 no good

8 ocean
1 old
1 ouch

41 road
8 rock
4 rocks
10 rocky
1 roof
2 round
2 rowdy
3 rude
1 rug
10 rugged
1 rush

6 sand
2 sandpaper
2 sandy
4 sea
2 shaggy
1 shake
1 shoes

7 tough
1 tree

1 uncomfortable
13 uneven
1 unkind
2 unlevel
2 unsmooth

1 voice

1 wall
4 water
2 waters
4 waves
1 wind
15 wood
1 work
1 wrestle

32. STORK

1 Africa
14 animal
1 animals

34 babies
287 baby
11 beak
26 big
16 bill
372 bird
2 bring
1 brook
1 brother
1 building

1 carried
2 carries
1 carry
1 chicken
1 children

4 chimney
1 colors
1 crane

1 dear
1 duck
2 Dutch

1 eat
1 eggs

1 fast
1 feather
6 feathers
1 fish
19 fly
1 flies
1 foot
1 fork
1 frogs

3 Germany
1 girl
1 going

1 have
1 head
9 Holland
1 house

1 I
1 is

1 kill

2 large
3 leg
41 legs
1 life
14 long
1 long-leg

11 long-legs

1 many
1 mean
1 meat
1 mother

4 neck
14 nest
1 nice

1 ostrich

1 plan
1 play

1 quick

1 river
1 rork

1 ship
1 shoot
1 shot
1 skin
1 slender
2 small
1 spaghetti
1 stole
1 stories
1 strange
1 swift

4 tall
1 talk

2 walk
3 white
4 wing
35 wings

33. FOOT

11 ache
1 afoot
15 ankle

1 ball
3 bare
2 barefoot
1 beat
27 big
1 black
11 body
10 bone
1 bones
1 boot
1 boots
1 bottom
16 break
7 broke
3 broken

3 clean
6 cold
21 corn
4 corns
1 crawls
2 cut

1 dog

1 fat
71 feet
1 figure
1 fingers
1 fleet
2 flesh
1 football

4 go
1 go on

1 had
5 hand
5 hands
1 heel
18 hurt
1 hurts

1 inches

2 jump

6 kick
1 kicked

1 ladder
1 lady
1 lame
6 large
1 leak
79 leg
36 legs
1 like
8 little
1 look
1 loot
11 long
1 lumber

12 man
1 march
1 measure
1 measurement
1 muscle
1 my

5 nails

1 one

1 people

1 piece
1 print

1 rough
1 rule
1 ruler
22 run
1 runs

1 shape
73 shoe
8 shoes
1 shot
5 skin
1 slipper
7 small
1 soothe
23 sore
1 sort
1 sour
1 square
1 stamp
1 stank
3 stand
11 step
1 stink

1 stockings
1 stool
1 strong
1 swollen

1 teacher
1 tiny
1 tired
34 toe
81 toes
1 track
1 twelve inches

1 useful

205 walk
3 walked
8 walking
38 walks
1 warm
1 wide
1 wiped
1 wonderful
1 work

1 yard

34. SPIDER

5 afraid
36 animal
1 ant
1 awful

1 cobwebs
1 cones
2 cook
1 corner

1 funny

1 glass
1 grown

4 lucky

1 mean
1 meat

2 sews
1 shanty
1 six legs
8 small

1 bad
1 banana
14 big
2 bit
25 bite
2 biter
5 bites
1 biting
4 body
1 boy
83 bug
1 build
1 burn
1 butterfly

1 catch
1 caught
1 claws
2 climb
12 cobweb

18 crawl
4 crawling
54 crawls
6 creature
2 crept
1 crow

1 daddylonglegs
1 dirt

5 eggs
1 enemy
1 eye

1 face
1 farm
6 feet
1 flee
40 fly
1 flyeater
9 fry

1 hang
1 head
1 hid
1 hoops
1 hornet
7 house

57 insect
1 insects

4 kill
4 killed
1 kind

1 large
1 leg
107 legs
17 little
19 long
11 longlegs

1 mider
1 Muffet

2 nasty
1 nice
1 no

4 pan
1 parlor
36 poison
2 poisonous
1 put

1 reptile
2 round
2 run
3 runs

1 scare
1 see
1 sew

1 soft
10 spin
6 spins
1 spun
1 stepped
2 sting

1 trap

3 ugly

19 walk
5 wall
1 wasps
261 web
2 webs
7 weave
1 wing
2 worm

35. NEEDLE

1 angry
1 article
2 awake

1 beetle
1 bench
2 bend
1 bumpy

8 cloth
1 clothes

1 doll
17 dress

41 eye

2 eyes

1 feather
7 finger
1 food

3 good

5 head
11 hole
3 hold
1 hurt

1 lamp
7 large
17 little

1 long

3 machine
2 mother

2 nickel

1 old

5 pick
1 pierce
36 pin
1 pins
23 point
5 pointed
16 prick

2 pricked

1 reedle

2 scratch
449 sew
3 sewed
1 sewer
81 sewing
3 sews
56 sharp
2 sharpened
3 silver
11 small
23 steel
39 stick

2 sticks
1 sting
1 stockings
1 string

4 thin
1 thing
72 thread
1 tin
1 tool

1 wire
6 work

36. RED

1 afraid
42 apple
14 apples
1 at

1 baby
6 ball
12 barn
1 bead
1 bell
1 bells
3 belt
1 bench
14 blood
9 blue
35 book
1 books
1 bow
1 box
1 bread
68 bright

1 calendar
6 candy
1 canoe
4 cap

1 children
1 Christmas
65 cloth
9 coat
1 cold
298 color
1 colors
1 cows
1 crayon

31 danger
6 dark
1 dirty
1 door
1 draw
85 dress
1 dresses

1 eraser

2 face
9 fire
24 flag
4 flower
2 flowers
1 fly

3 goods
4 green

10 hair
2 happy
5 hat
1 head
1 homely
1 hood
1 hot
7 house

4 Indian

13 lantern
2 led
1 letters
15 light
1 lip
1 look

1 morn

1 needle
2 nice

2 nose

1 orange

24 paint
1 painted
7 paper
1 papers
2 pencil
1 pillow
1 pinch
3 pink
14 pretty

1 radish
5 read
1 ready
1 remarkable
16 ribbon
1 riug
1 river
1 road
1 robin
1 rose
1 rosy
2 rug

1 run

1 sale
11 scarlet
2 school
1 see
1 shiny
1 sled
1 squirrel
1 star
1 stockings
1 story
10 sweater
1 Sweden

1 talk
1 that
1 thread

4 waist
1 wake
1 war
18 white
1 words

1 yellow

37. SLEEP

1 asleep
14 awake
1 awoke

28 baby
351 bed
31 beds

1 down
3 doze
55 dream
5 dreaming
6 drowsy
1 dust

1 keep

5 late
9 lay
1 lays
6 lazy
1 leap

1 peace
1 peacefully
1 people
8 pillow
1 pray

1 quiet

4 slept
6 slumber
15 snore
1 snores
1 snoring
24 sound
5 still

1 bird
6 boy
1 boys
1 bride
1 buggy

1 calm
1 candy
6 child
1 clean
5 close
1 closed
1 crept
1 cross

16 dark
1 did
1 do

1 enough
1 eye
40 eyes

1 fall
3 fast
1 fine

1 gentle
1 girl
1 go
7 good
1 goodnight

1 happy
1 hard

1 I

1 lie
1 lies
1 like
3 long

9 man
1 me
1 meet
1 morning
1 mothers
3 much

15 nap
4 need
3 nice
95 night

1 papa

1 quilt
12 quilts

40 rest
1 resting

1 see
1 senseless
1 she
1 sheep
1 sheet
5 shut
1 shutting
1 silent
4 sleeping
9 sleepy
1 sleepyhead
1 sleet

1 sweep

1 take
1 time
67 tired

1 uncle

6 wake
1 waken
1 we
1 went
1 will
1 woman
1 writing

1 you

38. ANGER

1 Alonzo
1 angrily
20 angry
1 ant
1 at

1 baby
17 bad
1 bashful
1 beer
1 bet
1 blow
38 boy
15 boys

1 children
10 cranky
1 cries
56 cross
1 crossness
1 cruel
6 cry

1 danger

1 disobey
6 dog

1 eat

1 fancy
4 fierce
57 fight
19 fighting
1 finger
1 flop
1 funny
1 furious
1 fury

3 girl
1 girls
9 glad
7 good
1 grave
1 greedy
1 grouch
1 grow
1 growl

1 hands
3 happy
1 harm
3 he
1 him
1 horse
1 hungry

1 I

6 kill
1 killed

1 lady
1 language
1 langer
1 large
1 lion
1 lookout

471 mad
1 madness
1 mamma
45 man

53 mean
1 mind
1 mother

1 naughty
6 nice

1 on

1 play

12 quarrel
1 quarreling
1 quick

1 rough

1 saucy
10 scold
3 scowl
1 sin
1 soften
9 sore
1 sorrow

1 spank
1 spanking
1 strong
7 swear

6 teacher
8 temper
1 tiger
5 tired

8 ugly
1 unhappy

1 very

1 walk
1 we
1 weary
1 whack
1 wicked
1 wild
1 wolf
11 woman

39. CARPET

20 beat
1 beating
9 beautiful
4 big
1 black
6 blue
1 border
9 broom
2 brown
1 brush
3 brussels

3 chairs
1 children
18 clean
19 cloth
16 color
3 colors
1 cover

1 design
1 designs
10 dirt
35 dirty

1 down
9 dust
15 dusty

1 fall
1 feet
1 felt
1 flat
149 floor
2 flowers
1 foot
2 front
2 fur
2 furniture

3 green

1 hall
1 have
12 home
30 house

6 large
2 lay

10 lays
1 like
1 little
1 long

1 man
1 marble
12 mat
1 mice
1 moth
1 mothers
1 muddy

15 new
15 nice

1 on

1 person
1 pit
1 poor
16 pretty
1 put

9 rag
4 rags
1 ragged
8 red
1 rolled
2 room
4 rough
245 rug
2 rugs
1 run

1 Saturday
1 shake
1 sing
5 small
7 smooth
28 soft
2 square
1 stain
1 stand
4 step
1 straw
45 sweep
1 sweeper

1 sweeps
1 swept

2 tack
20 tacks
1 the
1 thread
1 torn

6 velvet

88 walk
3 walked
1 walking
2 walks
1 warm
1 wash
1 we
1 weave
1 weed
1 wheels
1 will
1 wipe
1 women
1 woven

40. GIRL

1 anger

11 baby
34 beautiful

1 dolls
240 dress
23 dresses

1 her
6 home
1 homely
3 house

2 money

1 neat
24 nice

2 she
8 shoes
1 sing
4 sister

1 beauty
2 being
22 big
40 boy
1 boys
2 bracelet

1 cap
45 child
12 children
2 clean
26 clothes
1 clothing
1 coat
10 cook
1 creature
1 cry
1 curl
3 curls
1 cute

1 dancer
1 daughter
23 doll

2 eat
11 eyes

19 face
1 fair
1 fancy
5 feet
22 female
1 flirt
1 flower
1 foot
1 full
8 furs

1 giggle
2 girls
17 good
1 grow

38 hair
10 hands
1 happy
17 hat
1 have

6 human

1 June
1 jumping

7 kiss

1 lad
26 lady
5 laugh
1 legs
7 little
1 live
5 love

3 maid
2 maiden
1 Margaret
1 Marion
4 mate
2 me
5 mean
1 mirth
4 miss

1 Pearl
5 people
18 person
1 pies
1 plant
18 play
3 playing
2 playmate
3 plays
1 poor
25 pretty
2 punk

19 ribbon
5 ribbons
1 rill
3 run

21 school
1 scold
2 sew
1 sewed
1 sews

2 skirt
2 skirts
2 small
1 sole
2 stockings
11 sweet

1 talks
1 that
1 there

3 walks
1 wash
1 washes
1 went
1 where
1 wife
8 woman
1 women
8 work
1 wrangle
1 write

2 you
8 young

41. HIGH

2 above
4 aeroplane
9 afraid
50 air
4 airship
1 Alps
7 apple
10 apples
1 are

1 bakery
1 balloon
3 bank
1 beans
1 bees
14 big
5 bird
1 birds
1 blow
1 boy
1 build
32 building
1 bush
7 butter

1 cake
3 castle
8 ceiling
7 chair
1 children

9 church
1 class
10 cliff
1 climb
1 clock
3 clouds
3 cold
1 courthouse
1 crust
1 cut

16 deep
1 did
3 distance

1 ear
18 eat
3 eating
1 embankment
1 every

22 fall
58 far
1 fate
2 fence
1 flagpole
1 flower
1 flowers
24 fly

2 gastank
1 globe
1 goat
5 good
1 goodies

1 hair
1 hard
1 heaven
10 height
92 hill
1 home
32 house

1 in
1 iron

7 jump
1 jumped

1 king

1 ladder
1 large
3 length
1 light
8 long
1 look
1 loud
25 low

1 lumber

1 man
1 money
1 moon
120 mountain
5 mountains
1 my

1 nest
4 nice
2 nigh
1 number

1 oranges

2 peak
8 peaks
1 picture
1 post

10 reach
1 righ
1 road
1 rock
12 rocks
16 roof
1 room
1 rug

1 school

1 ship
1 sing
1 size
22 sky
1 so
1 stand
1 stars
30 steep
1 steeple
1 step
1 sun
14 swing

56 tall
1 thought
1 throw
1 tone
5 top
13 tower
7 tree
5 trees

60 up

3 very
1 vines

9 wall
3 way up
2 windmill

42. WORKING

3 bad
1 bank
2 beds
1 bench
1 better
1 blind
8 books
1 boss
7 boy
1 boys
1 bricks
1 build
49 busy

2 carpenter
1 chair
1 chop

1 driving
1 drudging
1 dust
1 dusting

10 earn
1 earning
1 eat

2 factories
6 factory
1 farm
6 farmer
1 fast
12 father
1 fireman

1 helping
7 home
20 horse
1 hot
1 house

6 job

18 labor
1 laboring
1 lace
1 late
13 lazy
2 learn
4 learning
1 light
4 loafing

3 noon
1 not

9 pay
1 people
1 pinch
34 play
11 playing
1 plumber
1 pop

1 rake
1 rate
9 rest

1 sand
1 saving

1 slow
1 stonequarry
1 stop
12 store
2 strong
11 study
2 sturdy
3 sweat

2 task
1 thrifty
29 tired
1 today
2 toil
1 ton
1 tools
1 tried

1	cigar
15	clothes
1	crust
8	day
1	digging
19	dishes
9	do
4	doing
1	done
1	doughnut
3	garden
2	girl
5	girls
1	good
1	hammer
1	hand
7	hands
299	hard
1	he
4	help
1	lumber
6	machine
1	machinist
1	make
93	man
1	mark
53	men
4	mind
1	mining
27	money
1	scholar
13	school
1	scrub
10	shop
1	shopping
2	shovel
1	shovelling
1	shovels
1	slave
1	sleep
1	sleeping
3	wash
1	well
10	woman
3	women
2	wood
19	work
2	worked
1	workman
1	workmen
1	wring

43. SOUR

47	apple
49	apples
7	ate
25	bad
63	bitter
1	boy
1	burns
3	buttermilk
3	cabbage
9	candy
1	cider
1	corn
1	cow
1	cranberries
52	cream
4	cucumber
1	dill
1	drink
54	eat
1	face
1	food
19	fruit
33	good
1	grape
8	grapes
9	green
13	hard
1	have
1	horrid
1	it
9	juice
1	juicy
1	kettle
8	kraut
57	lemon
3	lemons
1	liquid
1	lour
1	meat
124	milk
6	nasty
8	nice
1	no
1	not
1	onion
1	our
1	onions
8	orange
17	oranges
1	pancake
1	peaches
21	pickle
89	pickles
1	pie plant
1	pills
1	plum
1	plums
1	poison
1	radish
1	rotten
4	salad
7	salt
1	salts
4	sauce
1	scour
1	sorry
1	soup
24	sauerkraut
1	spoiled
1	sting
1	stomach
4	strong
1	sugar
75	sweet
28	taste
1	tasteful
1	tastes
1	that
1	things
1	too
1	tour
1	unhappy
1	unpleasant
1	unsweet
53	vinegar
1	very
1	warm
1	water

44. EARTH

4	air
1	awful
18	ball
21	big
2	birth
73	black
1	blue
1	boy
1	bright
1	brook
1	city
1	cloud
1	coat
3	cold
1	color
1	corn
1	deep
1	dig
1	dirth
102	dirt
1	dug
9	earthquake
1	feet
2	fertile
1	fire
2	flowers
1	food
3	frightened
1	froze
1	frozen
4	garden
4	globe
1	God
1	good
9	grass
2	gravel
2	green
1	grit
223	ground
1	grow
31	hard
7	heaven
5	hemisphere
3	high
10	hole
33	house
4	houses
1	in
1	is
43	land
34	large
1	light
38	live
1	lovely
1	man
1	meek
1	moist
1	mother
1	mountain
1	mud
1	muddy
2	nature
1	nice
1	nose
1	open
23	people
4	plant
1	plaster
5	play
5	quake
1	rabbit
3	roads
2	rock
1	rocks
5	rocky
1	rough
82	round
39	sand
2	seed
1	shack
1	shovels
1	sinking
6	sky
1	snow
1	sod
4	soft
4	soil
1	solid
3	sphere
2	star
1	step
1	stone
1	stones
1	stream
4	tree
3	trees
1	vegetable
15	walk
1	walking
3	warm
4	water
1	we
1	woods
1	work
30	world
1	worms
1	yard
1	you

45. GARDEN

1	angel
1	apple
36	apples
1	baby
15	beautiful
1	beet
13	big
5	cabbage
1	cakes
13	eat
2	farm
1	father's
2	fence
4	field
1	first
132	flower
327	flowers
2	food
1	fragrant
52	fruit
1	grown
9	grows
7	hoe
1	hoeing
1	I
4	land
1	large
1	lilies
6	nice
2	onions
1	pansy
1	pardon
3	peas
1	person
37	plant
1	planting
20	plants
1	raked
3	rose
5	roses
1	round
4	seed
8	seeds
2	shovel
1	soil
2	sow
3	summer

2	carrot
20	carrots
12	corn
1	club
1	den
10	dirt
9	earth
3	fruits
3	gardener
2	good
1	grand
1	green
19	ground
34	grow
5	growing
1	made
5	make
5	man
1	marden
1	men
1	mine
1	mother's
1	mud
3	play
1	poppies
3	potato
32	potatoes
5	pretty
2	pumpkin
3	radish
1	raise
3	tomatoes
28	vegetable
38	vegetables
1	weather
1	wet
2	yard

46. SOLDIER

1	am
1	are
1	armor
63	army
1	bang
14	battle
1	blue
3	boy
53	brave
1	bride
1	cadet
1	camp
1	cannon
24	captain
1	citizen
5	command
7	comrades
1	country
1	cruel
7	danger
3	dead
1	die
2	died
1	drill
1	enemy
160	fight
2	fighter
40	fighting
10	fights
1	flag
1	for
1	general
3	German
1	go
5	good
1	great
1	grows
9	guard
61	gun
1	guns
2	hard
2	hat
1	he
1	I
1	is
8	killed
1	leg
95	man
36	march
1	marches
6	marching
3	men
2	money
2	musket
1	navy
1	nice
1	of
4	officer
6	old
1	papa
1	patriotic
1	poor
1	powder
1	sad
1	save
17	shoot
4	shot
1	stab
2	stand
1	star
32	straight
8	strong
6	suit
26	sword
1	tall
4	uniform
1	United States
1	walking
203	war
1	warring
5	warrior
1	word
1	work
1	working
1	worries
2	worry
1	worth
1	wound
1	wounded
2	write
3	young

47. CABBAGE

1	apples
1	ate
1	bad
5	big
1	boiled
11	bugs
1	bread
3	carrot
9	cellar
42	cook
13	cooking
1	did
11	dinner
193	eat
1	eatables
9	eating
4	farm
1	field
2	fine
3	food
1	fresh
1	froze
1	fruit
1	garbage
46	garden
40	good
21	green
17	grow
1	growing
3	grows
3	hard
47	head
1	heart
1	house
1	hungry
1	I
1	it
2	kraut
1	lazy
9	leaf
62	leaves
1	lettuce
1	like
4	nice
3	patch
1	peeling
27	plant
2	pork
1	pot
1	potatoes
1	pumpkin
13	rabbit
25	rabbits
1	raw
2	roots
3	rotten
26	round
7	salad
1	sauce
1	saucer
34	sauerkraut
1	scent
2	sell
1	sick
6	smell
31	soup
12	sour
1	spareribs
1	spoiled
7	stewed
1	strong
1	stump
15	supper
3	sweet
140	vegetable
34	vegetables
1	well
9	white
4	worm
1	yard

48. HARD

13	apple
1	apples
5	bad
1	baked
16	ball
1	bard
1	bat
1	bed
5	big
2	bite
2	black
26	board
1	bone
1	bones
39	bread
28	break
1	breakable
1	can't
2	cement
4	chair
1	chalk
1	chosen
2	chunk
1	coal
1	cracked
9	crust
1	desk
13	dirt
1	do
1	door
17	earth
1	easy
4	hand
10	heavy
3	house
2	hurt
33	ice
1	ice-cream
36	iron
1	jelly
4	lard
1	log
1	look
3	lump
1	man
1	Marie
1	pound
1	press
1	pudding
1	radiator
1	ring
1	road
92	rock
1	rocks
1	rocky
29	rough
1	rub
1	sharp
1	sidewalk
1	slippery
25	smooth
14	snow
1	strong
1	stuck
1	sweep
1	tack
1	test
1	that
1	there
1	thick
1	thing
1	throw
7	tough
1	very
1	was
1	water
1	winter

22 brick
1 bricks
1 bumpy
1 butter

1 cake
1 can
48 candy

1 fight
54 floor
1 frozen

4 glass
1 good
51 ground

2 mean

3 nut

1 old

4 packed
1 plate
2 play

65 soft
17 solid
1 sore
1 sort
1 sound
4 stiff
113 stone

30 wood
1 word
89 work
1 worker
2 working
1 worry

49. EAGLE

1 air
19 American
1 angry
6 animal

11 baby
1 banner
2 beak
2 beast
1 beater
52 big
2 bill
373 bird
2 birds
3 bite
6 black
1 bregle

1 chicken
1 child
30 claws
1 cliff

3 cloud
1 condor
1 coward

1 dog

6 eat
1 eggs
1 emblem
1 eyes

9 feather
28 feathers
1 fierce
2 flag
1 flew
26 flies
120 fly
10 flying

1 gander
1 good

3 gray

2 head
1 hen hawk
6 high

1 imagination
1 insect
1 insects
1 invisible

1 kidnap
1 kill
1 king

1 lamb
19 large
1 lodge

3 mad
3 man

9 mean
1 miegle
35 mountain

1 name
18 nest

2 owl

1 play
2 pretty

1 reagle
1 robber
2 run

1 savage
2 scratch
1 seven
2 show
1 size
1 slide

1 small
1 soar
1 steal
1 strength
30 strong
1 swift
1 swoop

1 talons
1 teeth
3 thief
1 took

4 United States

2 warbird
1 white
43 wing
49 wings
1 work
1 wrong

50. STOMACH

189 ache
3 aches
1 apples
1 ate

13 bad
1 ball
48 belly
1 belt
3 big
2 bladder
2 blood
78 body
2 bones
1 born
4 bowels
9 boy
3 bread
3 breast
2 breathe
1 brick

1 candy
4 care
4 chest
2 clean
1 close
1 cold

2 cramps

8 digest
1 digestion
1 dinner
1 doctor
1 drouth

2 each
108 eat
1 eatable
16 eating
1 eats
5 empty

1 fall
1 false
16 fat
1 feed
2 feeling
1 feet
1 felt
2 flesh
82 food
1 for food
19 full

1 garbage
23 good

1 grind
1 grow
1 guts

1 had
1 hammock
3 hard
7 healthy
21 heart
1 heavy
1 hill
6 hungry
23 hurt
5 hurts

1 I
5 indigestion
9 inside
6 insides
1 intestine

4 kidney

1 lazy
1 light
1 little
1 liver
1 lumic
6 lungs

1 meal
2 mean
1 meat
1 milk
1 music

1 name

1 out

18 pain
1 people
1 person
10 poor
1 pudding

1 rice
1 ring
1 rock
1 rotten
3 round

1 see
1 short
85 sick
1 sickness
13 skin
1 soft

22 sore
1 sound
3 sour
1 steak
1 stick
1 stone
1 stumble
1 swallow

3 throat
1 tomato
2 treat
1 tripe
11 trouble
1 tube

1 veins
1 velvet
1 vital

1 warm
1 water
15 weak
1 well
3 white
1 wood

51. STEM

25 apple

1 bad
1 beginning
1 bend
1 bent
1 berries
14 big
1 bitter

15 corn
1 crooked
41 cut

1 down

1 earth
1 eating
8 end

1 hard
1 have
1 hold
1 holds
3 hollow

14 juicy

1 large

1 pick
1 pin
42 pipe
25 plant
1 plants
1 point

1 red
2 reed

1 string
1 strong
1 sugar
1 system

5 tall
1 them
1 thick
11 thin

1 black
1 blossom
1 boat
1 body
1 bone
1 bough
16 branch
1 broke
20 broken
1 brown
1 buds
1 burn

1 came
1 cord

1 firm
367 flower
80 flowers
1 foot
1 froze
1 fruit

1 gray
1 grass
48 green
1 ground
9 grow
1 growing
1 grows

11 leaf
1 leaves
3 letter
3 lily
6 limb
60 long
1 look
1 lots

1 paint
1 paper
1 part
1 paste
1 pen
1 pencil

13 root
3 rose
1 roses
1 rough
1 rubber

4 short
6 slender
3 slim
1 small
1 sort
4 stalk
1 stand
10 stick
2 straight

1 top
35 tree
1 trees
1 trunk
9 twig

1 vine

8 weed
1 white
1 wide
8 wood

52. LAMP

1 bedtime
3 big
1 blaze
1 blow
1 blue
1 box
3 break
8 bright
1 broke
1 broken
70 burn
1 burns
10 burning

1 camp
1 cat

1 ceiling
18 chimney
1 color
1 command

1 damp
1 dark
1 desk
1 down

1 exploded
1 explosion

22 fire
9 fires
3 flame

12 gas
50 glass
5 globe
3 good

1 hanging
1 hard
1 have
10 home
1 hook

1 is

4 kerosene
1 kitchen

1 lantern
648 light
4 lights

1 nice
6 night

38 oil
1 oily
3 out

1 pretty

1 red

3 see

4 shade
2 shine
1 sleep
1 small
2 smoke
1 stamp
4 street

1 tipped

1 white
19 wick
1 wool

1 yellow

53. DREAM

2 about
6 afraid
1 alas
1 Alice
2 angel
1 angels
1 animal
7 asleep
5 awake
4 awful

2 baby
31 bad
1 bear
1 bears
20 beautiful
78 bed
1 bedtime
1 bird
1 boat
1 book
6 boy
1 burglar

1 can
1 car
1 cat
1 children
1 cream

1 cry

4 dark
1 day
1 dies
3 do
1 doll
1 doze
2 dreaming
1 dreamland
1 dreamt
1 dresses
1 drowsy

1 fairies
3 fairy
2 fairyland
1 fierce
4 fight
4 fire
1 flowers
3 fun
13 funny

4 ghost
7 girl
1 gleam
20 good

1 happened
12 happy
1 hear
1 her
2 horses
1 house

1 imagination
8 imagine

1 lady
1 lake
1 laugh
1 lessons
1 like
1 lions
3 long

8 man
1 mare
1 mine
1 money

1 never
9 nice
260 night
3 nightmare
1 noise
1 nothing

3 picture
1 pictures
9 pleasant
1 position
1 pretty

1 quiet

1 rats
1 ream
1 robbers
1 rose

1 Santa
1 scared
1 school
1 scream
4 see
1 sister
272 sleep
8 sleeping
1 sleepy
4 something
1 spirit
6 stories
8 story
6 strange
1 sweet

1 talk
1 tell
5 thing
13 things
30 think
2 thinking
3 thought
1 thoughts
1 train
1 true

1 used

4 vision
1 visions

1 war
1 was
1 water
1 way
1 what
2 window
5 wonder
4 wonderful
1 wondrous

1 yell

54. YELLOW

3 apple

1 ball
11 banana
1 beautiful
1 bed
1 bicycle
4 bird
1 black
1 blossom

1 coat
1 corn
320 color
1 colored
3 colors
1 cream

4 daisy
15 dandelion
1 dark

3 golden
10 goldenrod
1 good
9 green

3 hair
1 hair ribbon
1 hall
3 hat
1 honey

8 nice

81 orange
1 oranges

21 paint
1 pale
1 pants
3 paper
1 peach

1 ruler

2 saffron
1 sea
1 shine
1 silk
1 skin
1 spelling
1 stars
1 suit

[illegible]

[illegible]

[illegible]

United States

[illegible]

[illegible]

[illegible]

2 blue
1 body
1 boyhood
3 boys
3 brave
2 bright
1 brother
1 bum

53 cap
45 child
14 children
1 clean
9 clothes
9 coat
1 color
1 cows
1 creature

1 darkey
2 dirty
1 do
1 driving
1 drum

1 eager
1 fights
1 fish
1 fishng
7 football
1 foy
1 frank
8 fun
1 funny

6 games
2 gentleman
32 girl
1 girls
1 go
37 good
1 grocery
2 grow
1 growing

5 hair
1 haircut
1 happy
1 hard
6 hat
6 he
7 head
1 John
1 jump
1 Junior

10 kid
1 killed
1 kites

1 lad
2 large
1 laugh
1 lazy
3 leg
1 like
1 limbs
12 little
1 living
1 loy
1 luck

4 mad
9 male
61 man
5 marbles
1 master
2 me
1 no

63 pants
5 people
26 person
84 play
1 playful
3 plays
1 poor
1 pretty

1 quick

1 race
1 read
1 red
1 rich
1 romp
18 rough
1 Roy
18 run
3 running
5 runs

11 school
1 see
6 snowball
4 son
1 store
7 strong
6 suit
1 swim

2 tie
1 toe
1 toes
2 toy
1 trouble
16 trousers

1 Vivian

2 waist
2 wagon
1 walk
1 walked
1 wear
14 whistle
29 work

4 young

58. LIGHT

1 Aladdin
5 air

1 baby
1 barn
1 beautiful
1 bird
1 black
1 blaze
1 book
1 boy
1 bread
74 bright
1 brighter
5 burn
1 burned
4 burning

2 candle
5 clear
1 coal
11 color
1 complexion
1 cotton

99 dark
1 dawn
67 day
1 daytime
2 dirt
1 dog
1 dress

6 easy
5 electric
1 enough
2 eyes

1 fair
5 feather
19 fire
1 flame
1 flash
1 flowers

64 gas
1 glad
1 glass
47 good
1 grate

5 hair
1 hall
1 hard
1 headlight
1 heaven
4 heavy
1 help
1 home
9 house

1 is

1 kerosene

251 lamp
2 late
1 lighting
1 lights
1 like
4 look

2 man
18 match
1 matches
1 mean
2 might
4 moon
6 morning

4 nice
10 night
1 noon-day

1 oil
3 out
1 outside

4 paper
1 penny
1 pin
2 pretty
3 poor

1 radiant
1 read
5 red
6 room

43 see
1 seen
2 shade
1 sharp
30 shine
2 shines
3 shining
1 ship
2 shone
2 sky
4 soft
1 star
1 stone
1 store
2 strong
2 suit
29 sun
1 sunny

1 thought
1 to-day
1 tower

1 up
1 us

1 walk
3 want
2 warm
17 white
12 window
1 windows
4 work
2 write
1 writing

9 yellow
9 yes

59. LAUGH

1 ache
3 aloud
1 always

7 baby
14 boy
1 boys
1 burst

1 calling
1 cat
1 chatter
2 cherry
27 children
1 clown
1 comical
1 cough
1 crazy
1 crow
14 cry

2 do
2 enjoy
1 enjoying
1 easy

7 face
2 fine
138 fun
97 funny

1 gay
22 giggle
33 girl
1 girls
26 glad
3 gladness
1 glee
9 good
3 gun

10 ha ha
4 happiness
78 happy
28 hard
4 hearty
1 hiccough

7 joke
1 jokes
50 jolly
53 joy
1 joyful

1 lady
3 laughed
2 laughing
7 laughter
1 like
2 lips
2 long
1 lot
38 loud
1 lumber

1 makes
4 man
3 me
20 merry
1 monkey
4 mouth

3 noise

1 people
1 person
1 play
2 pretty

1 Santa
1 set
2 she
1 shout
2 show
1 sideache
2 silly
1 sing
150 smile
5 smiling
1 sober
3 something
1 squeak
35 sweet

9 talk
1 talked
1 teeth
1 tickle
1 tickled
1 time

1 weak
1 wide
1 with
5 woman
1 women
1 wrong

6 you

[illegible]

[illegible]

scripture

stories

story

7 study
11 Sunday
1 swear
1 sweet
4 teach
1 teaches
1 tells
5 Testament
1 text
3 think
3 true
3 truth
4 verse
5 verses
5 words
2 world
1 write

[illegible]

[illegible]

little

milkman

36 sour
1 spill
1 sugar
1 swallow
25 sweet
1 toast
1 thin
4 warm
8 water
91 white

[illegible]

[illegible]

meadow

meat

milk

money

mutton

6 one

paper

pasture

pet

play

poor

pretty

1 ram
1 range
2 run
1 sewing
3 shear
32 shepherd
1 shepherds
skin
1 slip
1 steak
1 stock
1 track
1 walk
1 walked
1 wash
57 white
411 wool
1 woolen
1 woolly

63. BATH

[illegible]

healthy

house

person

river

robe

4 room

3 take
1 toilet
4 took
6 towel
131 tub

3 bathing
1 bathroom
4 bathtub
1 bird
1 body
5 boy
1 boys
1 but

1 camp
192 clean

1 door
1 dress

1 fresh
1 feet
3 fire

1 girl
11 good
5 had
1 happy

1 last
1 like
7 little
1 lot

1 naked
1 naughty
1 neck
7 nice

1 run
20 Saturday
4 scrub
4 shower
1 sink
8 soap
1 splash
9 swim
3 swimming

1 wade
10 warm
143 wash
1 washing
1 washtub
295 water
1 week

2 yesterday

64. COTTAGE

1 age

1 bad
4 big
1 blotch
1 brown
3 bungalow
1 burnt
1 buy

1 carpet
1 chair
39 cheese
1 children
1 clean
1 comfortable
2 cot
6 country
5 cozy

1 cute

1 dirty
1 door

2 farm
1 father
1 funny

2 good

101 home
1 hot
425 house
9 hut

1 lady
117 lake
34 little

79 live
1 lived
1 lives
1 log

1 man
1 matey

1 neighbors
1 news
12 nice

1 paint
1 paper
1 plain
1 poor
3 porch
1 pretty

1 rain

1 red
1 rent
1 residence
1 river
1 roof
2 room
2 root
1 run

3 school
1 sea
1 shack
1 shanty
1 shelter
1 shoot
2 sleep
36 small
2 snug
3 stove
14 summer

1 swimming

2 take

3 village

4 warm
1 we
1 where
1 wife
2 window
1 women
17 wood
2 wooden
14 woods
1 work

1 yard

65. SWIFT

1 actor
3 air
3 arrow
11 auto
6 automobile

1 baby
5 ball
2 baseball
1 beat
3 bicycle
2 bird
1 birds
3 boat
1 boy
1 breath
1 bring
1 broom
1 bullet

1 can

2 care
1 car
3 cars
1 company
11 current

4 deer
1 drive

1 engine

1 falls
391 fast
7 feet
1 firehorses
1 fleet
8 fly
3 foot
1 footed

4 go

1 goes
3 going

1 Hiawatha
124 horse
3 horses
1 hose
4 hurry

1 kick

1 lard
1 legs
2 lift

1 meal
1 motor
1 mouse

1 nest
1 not

10 quick
1 quite

1 rabbit
11 race
1 raise
7 ran
1 read
4 reindeer
1 ride
1 rider
1 riding
1 ring
14 river
1 rough
1 round
202 run
13 runner
16 running
1 runs

1 Santa
1 see
1 skate
1 sled
1 slight
28 slow
4 speed
1 stream

1 threw
1 time
1 to
15 train

3 wagon
8 water
3 went
4 wind
1 work

1 you

66. BLUE

3 air
1 any
1 apron

1 bad
1 bag
2 ball
2 balloon
1 bean flower
1 beautiful
1 beauty
1 bell
4 big
4 bird
3 black
1 blood
1 blossom

1 boy
1 bread
24 bright
1 brown

1 circus
1 clean
4 cloth
1 clothes
6 coat
318 color
1 crew

12 dark
1 dirty
1 draw
173 dress

6 flower
1 fly
1 forgetmenot

1 globe
1 good
1 goods
1 green

1 hard
4 hat
3 high
2 horn
9 house

1 I
3 ink

1 light blue
1 line

1 mark
1 match
1 mew

2 navy
3 nice

22 paint
6 paper
3 paste
1 pastry
10 pencil
2 picture
15 pretty
2 sad

1 sea
1 silver
1 sister
1 skirt
102 sky
2 stick
3 sticky
1 stocking
12 suit
1 sweater

6 true

1 very

1 violet

3 waist
3 water

[illegible]	[illegible]	[illegible]	[illegible]	1 whistle
[illegible]			purple	1 wild
[illegible]	[illegible]	[illegible]		34 wind
[illegible]	[illegible]	[illegible]	red	1 windy
[illegible]			red, white & blue	1 writing
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	ribbon	1 yellow
[illegible]	[illegible]	[illegible]	round	

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	1 table
[illegible]		[illegible]	[illegible]	1 taste
[illegible]	[illegible]	[illegible]	[illegible]	1 tasty
[illegible]	[illegible]	[illegible]	people	1 terrible
[illegible]	[illegible]	[illegible]	[illegible]	1 than
[illegible]	[illegible]		[illegible]	1 thin
[illegible]	[illegible]		[illegible]	1 thirst
	[illegible]	[illegible]	[illegible]	13 thirsty
[illegible]	[illegible]		[illegible]	1 time
[illegible]		[illegible]	[illegible]	3 tired
[illegible]	[illegible]			1 too
[illegible]	[illegible]	[illegible]	[illegible]	1 tramp
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		3 very
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		school	1 wait
[illegible]		[illegible]	[illegible]	6 want
	[illegible]	[illegible]	[illegible]	1 wants
[illegible]	[illegible]	[illegible]	[illegible]	2 wanting
[illegible]	[illegible]	[illegible]	small	1 war
[illegible]	[illegible]	[illegible]	[illegible]	1 warm
	[illegible]	[illegible]	[illegible]	1 was
[illegible]	[illegible]	[illegible]	[illegible]	1 water
[illegible]	[illegible]		starve	[illegible] weak
[illegible]	[illegible]	[illegible]	starved	3 wolf
[illegible]		[illegible]	starving	[illegible] woman
[illegible]	[illegible]	[illegible]	stomach	[illegible] work
[illegible]		[illegible]	sugar	
[illegible]	[illegible]	[illegible]	supper	[illegible] yellow
[illegible]			sweet	[illegible] yes
[illegible]	[illegible]	[illegible]		[illegible] you

[illegible] PRIEST

[illegible]	[illegible]	[illegible]	[illegible]	[illegible] speaker
	[illegible]		[illegible]	[illegible] speaking
[illegible]	[illegible]	[illegible]	[illegible]	3 speech
[illegible]		[illegible]		16 Sunday
[illegible]	[illegible]		[illegible]	[illegible] Swede
[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] talk
[illegible]	[illegible]	[illegible]	[illegible]	1 talks
[illegible]	[illegible]	[illegible]	[illegible]	4 teach
[illegible]	[illegible]	[illegible]	[illegible]	2 teacher
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] tear
[illegible]		[illegible]	[illegible]	[illegible] there
	[illegible]			[illegible] think
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	school	[illegible] wagon
[illegible]	[illegible]	[illegible]	[illegible]	1 ward
[illegible]		[illegible]	[illegible]	[illegible] wedding
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] where
[illegible]	[illegible]	[illegible]	[illegible]	1 white
[illegible]	[illegible]	[illegible]	[illegible]	1 wife
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] worship

[illegible] OCEAN

[illegible]	[illegible]	[illegible]	salty	1 the
[illegible]	[illegible]		[illegible]	1 Titanic
		Pacific	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] war
[illegible]		[illegible]	[illegible]	413 water
[illegible]	[illegible]		[illegible]	8 wave
[illegible]		[illegible]	shell	88 waves
[illegible]	[illegible]	[illegible]	ship	1 wavy

20 boats

1 calm
1 coast

23 deep
1 dip
14 drown
1 drowned

13 lake
1 lands
4 large
4 liner

1 New York

1 on

36 river
3 roar
5 rough
1 round

3 sail
1 sails
6 salt
1 saltwater

36 ships
1 shore
1 sky
1 sponge
1 steamboat
11 steamer
1 steamship
1 swift
2 swim

1 were
1 whale
1 whales
1 wharf
35 wide
1 wild

70. HEAD

22 ache
13 aches
1 aching
1 army

1 band
1 ball
1 bed
15 big
1 bird
1 black
1 blood
26 body
1 bone
3 boy
2 braid
25 brain
137 brains
1 bumps

6 cabbage
2 captain
1 chest
8 chicken
1 clean
1 cloth
1 comb
3 cut

1 dead
1 dog
3 doll

2 ear
2 ears
1 eat
1 elephant
16 eye
91 eyes

42 face
1 fat
1 fill
1 fish
1 fist
9 forehead
1 funny

1 girl
5 good
1 grant

203 hair
1 hang
3 hard
12 hat
1 hats

3 headache
2 hear
1 hog
2 horse
1 human

1 it

2 large
5 lead
2 learn
1 light
2 listen
4 little

1 made
10 man
3 memory
46 mind
1 mine
9 mouth
1 move
1 my

2 nails
2 neck
1 nerve
1 nerves

12 nose
1 nut

3 off
1 on

1 part
3 people
5 person

1 quarters

1 red
1 rough
58 round

1 sausage
3 scalp
1 school
8 see
2 sense
1 sings
14 skull
1 sleep
9 small
1 smiles
1 soft

1 sore
1 sparrow

5 talk
1 talker
2 teeth
1 there
59 think
2 thinking
1 thinks
6 thought
1 top

1 up
3 use

1 veins

1 warm
1 were
1 white

1 yours

1 zebra

71. STOVE

1 bake
1 baking
5 big
37 black
1 blue
1 broken
103 burn
8 burning
6 burns

1 chimney
16 coal
1 coke
7 cold
62 cook

3 cooking

1 damper

1 exploded

1 fill
164 fire
2 fry

1 gas
1 girl
1 going
1 good

1 hair
3 hard
117 heat
3 heater
1 home
200 hot
1 house

45 iron

1 kitchen

2 legs
1 lid
1 little

1 log
1 love

1 match
1 move

1 nice
1 nickel

2 oven

1 paper
12 pipe
6 polish

5 range

1 rat
1 red
1 rusty

2 smoke

8 use

127 warm
8 warmth
1 went
5 winter
11 wood
1 world

72. LONG

2 ago
1 arrow
4 away

1 bad
55 big
1 bird
1 black
1 blaze
9 block
11 board
4 boat

1 cabin
2 cakes
1 car
1 cat
1 chain

1 engine
1 eraser
1 every

1 face
90 far
1 feet
1 field
1 figure
1 find
1 finger
23 fingers
1 fish
1 flat
1 floor
1 flower
1 flown

1 lanky
7 large
7 legs
25 length
2 lengthy
1 lesson
3 line
1 log
1 lonesome
2 longer
1 long for
1 lots

7 man
1 mane
1 measure
9 mile
2 miles

1 read
12 ribbon
6 ride
9 river
4 road
4 room
26 rope
1 rough
1 rug
6 ruler

1 sad
3 school
1 see
1 shirt
45 short
3 shout
2 sidewalk

2 table
1 tail
1 tale
33 tall
1 telephone
1 ten
2 thin
3 thing
1 thong
1 thought
1 thread
41 time
1 Tipperary
2 tiresome
5 train
1 tree
2 trip

6 skinny
skirt
skirts
slender
slim
slow
small
smoke
[illegible]
start
spring
4 stay
stick
store
4 stuck
story
straight
stream
street
strong
swing

1 verse
4 very
1 visit

1 wagon
8 wait
1 waiting
5 walk
1 wall
1 want
31 way
1 while
12 wide
4 width
2 wish
1 wood
2 word
1 worm

3 yard
2 years

73. GHOST

party
person
play
[illegible]
pretty

[illegible]
[illegible]ther
[illegible]
4 [illegible]

saw
scare
scarecrow
scared
scares
see
[illegible]
[illegible]
sheet
[illegible]
sight

2 silent
8 skeleton
1 small
36 spirit
8 spook
1 spooky
1 story

1 teacher
2 Thanksgiving
1 think
1 true

2 vision

364 white
1 wig
4 witch
1 woman
2 wood

1 you

74. WHISKEY

man
mean
medicine
men
much

name
nasty
[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

rum
rye

saloon
9 sick
strong

tantalizing
taste
temperance
1 tiger
1 tonic

8 water
1 wet
wild
wine

75. CHILD

[illegible]
nature
naughty
nice
niece
nurse

[illegible]

people
person

sickly
1 sister
1 six years
sleep
45 small
smart
1 spirit
steal
1 stocking
3 stork

8 candy
94 children
1 Christ
5 clean
13 clothes
1 clothing
1 cold
1 creature
1 cries
21 cry
1 crying
5 cute

1 dance
1 daughter
1 dead

5 friend

1 get
93 girl
78 good

3 hair
2 hand
1 hands
1 happy
1 hat
2 head
1 hid
1 hood
1 house
1 human
1 humor

48 little
3 lost
8 love

1 mad
1 mamma
5 man
1 meal
2 mean
1 milk
1 mind
1 mine
1 mischief
26 mother
1 mothers
4 myself

1 pile
36 play
2 playing
4 plays
11 poor
1 pretty
1 pupil

1 ribbon
1 ride
12 run
2 running
2 runs

12 school
1 scold
1 sick

1 strong
1 sturdy
1 sweet

1 take
1 that

1 walk
1 warm
1 well
1 while
1 white
1 won't

3 young

76. FRIEND

1 acquaintance
1 acquainted
1 afraid
1 Alice
1 America
1 Annie
1 August
4 aunt

2 bad
1 bend
19 best
112 boy
3 boys
1 Brady
3 brother

1 Carl
3 children
1 chick
98 chum
1 clean
1 Clifford
1 Clint
10 companion
5 company
2 comrade
1 country
1 course
66 cousin
1 cousins
1 cross

2 dead
1 dear
1 death
2 dog

1 Edith
1 Edna
1 Elson
4 enemy
1 Evelyn
1 everyone

1 father
1 fellow
3 fight
1 fire
1 foe
14 friends
4 friendship
2 fun

1 gentleman
118 girl
1 girls
2 go
1 gone
94 good
1 got

1 happiness
10 happy
8 have

2 he
1 help
1 hend
1 him
1 horse
1 hurt

1 Ida
1 invite
1 Irish

1 John

1 killed
6 kind
2 kindness
8 know

11 lady
2 lend
6 like
1 little
1 Louise
23 love
1 loved
1 lovely

1 mad
8 man
4 marry
1 Mary
55 mate

1 mates
1 mean
1 meet
3 mine
1 money
4 mother
1 move
1 Mrs.
6 my

1 name
22 neighbor
2 nephew
13 nice
1 no
1 nobody
1 now

1 over

1 pal
2 pals
1 park
2 partner
15 people
25 person
35 play
2 playing
35 playmate
1 playmates
1 plenty
1 pretty

1 Rea

1 red
2 relation
4 relative
1 rend
1 ring
1 Roy

3 school
4 schoolmate
1 see
1 she
1 ship
1 sick
1 sing
1 skin
1 smoke
1 some one

1 this

1 visit
1 visiting

1 walk
2 war
1 who
2 with
1 women

1 years
8 you
1 your
2 yours

77. HAMMER

1 axe

1 baby
1 beat
1 big
1 blacks
1 blacksmith
1 board
1 broken
1 build
2 building
1 busted

1 carpenter
5 chop
1 club
1 crack

1 drive

37 finger

1 good

1 hand
9 handle
1 happy
20 hard
3 hatchet
1 have
1 head
1 heavy
32 hit
4 house
2 hurt

62 iron

2 knock

1 lead
6 little
5 loud
1 lumber

1 make
1 manner
1 man

218 nail
186 nails
1 new
6 noise
1 noisy
2 nuts

1 ouch

1 papa's
1 pieces
288 pound
1 pounded
1 pounder
28 pounding
4 pounds

1 rammer
1 rap

1 saw
1 slam
2 sledge
1 smash
2 sore
1 square
1 steel
1 strike

4 strong
1 swings

1 tack
11 tool
3 tools

2 use

1 we
7 wood
2 work
1 works
1 workshop

1 your

78. THIRSTY

2 am
4 are

1 baby
3 beer
1 burning

2 camel
2 cat
3 child
1 choke
3 coffee
1 cooking

3 crow
3 cup

1 dog
4 drank
364 drink
1 drinker
1 drinking
132 dry

1 filled
1 food

9 girl
1 going

1 home
1 horse
1 hot
17 hungry

1 lemonade
1 lonesome

1 mad
6 man

11 milk
1 mother

3 parched
1 pop
1 pump

4 quench
1 quenched

4 salt
1 starve

1 thirst
1 throat
4 tired
1 too

1 very

8 want
1 wash
377 water
2 weak
1 well
2 women
1 would

79. CITY

1 air
1 automobile

3 beautiful
1 Berlin
124 big
4 block
7 blocks
2 building
5 buildings
1 burned
1 burning
2 burnt

1 canal
2 capital
2 car
2 cat
11 chair
3 cheer
1 church
20 citizen
4 clean
6 clothes
1 coming

1 corner
3 council
86 country
1 crowd

1 dark
5 dirt
10 down
1 dust

1 eat

1 folk
2 fun

2 go
1 going
3 good

1 hill
22 home
2 horse
1 hospital
15 house
14 houses

1 I
1 inhabitants
1 it

1 July

1 lady
4 lamp
5 land
40 large
2 lighted
1 lights
1 like
1 line
2 little
1 lity
50 live
2 lived
1 lone

1 made
1 majority
8 man
2 men
218 Minneapolis
10 Minnesota

4 name
2 New York
2 noise

1 oblong
1 old

1 Paris
3 park
1 paving
44 people
1 place
1 president

1 rat
1 rest
1 resting
1 roads
2 rocks

2 seat
2 seated
1 sewer
1 sidewalk
1 sit

27 state
5 store
12 stores
1 story
1 story
2 St. Paul
12 street
5 streetcar
2 streets

1 table
1 tired
1 Toledo
110 town
1 travel
1 Turkey

1 United
2 U. S.

2 village
1 visit

1 wagon
1 wagons
3 water
1 we

80. SQUARE

1 acre
1 arithmetic

1 back
1 bear
9 big
1 bills
3 blackboard
300 block
4 blocks
7 board
15 book
80 box
1 boy
4 brick
1 Bridge
1 building

1 cake
1 cakes
1 candy
1 cards
1 case
1 carpet
1 cell
2 chair
2 circle
1 cloth

83 corner
6 corners
1 cube

1 deep
4 desk
1 door
1 draw

4 edges
2 equal
1 eraser
20 even
7 exact

1 feet
1 figure
3 flat
2 floor
1 foot
3 four
1 four-cornered
1 fraction

2 game
1 goods

1 handkerchief

1 hole
23 house

2 ice
1 in
29 inch
3 inches
1 isn't

2 Jackson

11 large
1 length
1 lengthwise
1 letter
1 level
4 line
1 lines
1 log
17 long
3 lot

1 make
1 map
1 market
1 mats

1 nice

2 not
2 not round

95 oblong
1 one

28 paper
4 park
1 parts
2 perfect
4 picture
2 piece
4 place
1 plank
1 plate
3 play
1 plot
1 public

1 right
4 ring
1 rock
1 rod
6 room
35 round
3 rug
8 ruler

1 school
1 schoolhouse
8 shape
1 sharp
1 shoulders
2 sides
2 sidewalk
1 small
1 so
1 soldiers
1 stand
1 steel
1 steeple
30 straight
1 sugar

5 table
1 that
6 thing
1 tool
1 town
1 triangle

2 walk
1 while
12 wide
3 wood

5 yard

81. BUTTER

1 bad
467 bread
1 brown
10 butterfly
1 but

1 cheap
13 cheese
18 churn
15 cow
5 cows
30 cream
5 creamery
1 cubes

9 dairy
1 dandy
1 dear
3 dish

122 eat
2 eatable
1 egg
1 eggs

1 farmer
19 food
6 fresh

1 goat
37 good
5 grease
1 greasy

2 hard
8 high
1 house

1 I

1 knife

1 lard
1 like

1 love

1 made
1 man
3 melt
47 milk
1 mutton

1 nice

1 on

1 pail
1 pound

1 salt
1 salty
1 scatter
5 smear
8 soft
5 spread
1 square
3 store
4 sweet
1 syrup

1 taste

1 where

117 yellow

82. DOCTOR

1 auto

7 baby
1 bad
1 bed
9 bill
1 bottle
1 brother

1 call
6 care
3 case
1 cauterizer
1 child
1 colds
6 come
2 coming

1 cough
24 cure

2 dentist
1 did

2 examine

1 family
1 father
1 find

40 good

7 heal
1 healer
1 heals

15 health
10 help
1 helper
1 helpman
5 helps
3 home

4 ill
4 illness

1 Johnson

1 lawyer
1 lay
1 learn

1 major
1 mamma

132 man
136 medicine
2 men
2 mother

1 needed
1 nice
13 nurse

1 office

6 physician
1 pills

1 queer

1 rain
3 rich

1 satchel
1 scar
448 sick
34 sickness
3 sore

1 tag day
1 teeth
1 tools
1 treat
1 treatment
4 trouble

1 visit

1 was
30 well

83. LOUD

1 able

1 baby
1 bad
2 bang
2 bark
1 bear
3 bell
1 blast
1 boy
1 boys
1 bugle

28 call
1 called
1 calling
1 cannon
1 cause
5 child
1 children
1 coarse
1 color
1 cried
29 cry
1 crying

5 deaf

3 dog
1 door
1 drum

1 ears
7 echo
1 echoes
1 every

8 far
1 fast

1 going
1 gun

1 hammer
12 hard
7 harsh
28 hear
1 heard
1 hoarse
190 holler
3 hollering
1 home
6 horn
3 howl
1 howling

1 I
1 it

3 laugh
1 laughed
1 like
7 long
1 louder
5 loudly
8 low

1 man
1 men
1 mouth
1 moving
4 music

201 noise
11 noisy
1 not

1 peal
1 peals
4 piano
1 plain
1 pound
1 proud

1 rags
1 read
1 reading
1 recite
1 record
6 ring
1 roud
1 rough

15 scream
1 sharp
1 shot
21 shout
1 shouted
3 shriek
3 shrill
1 silent
20 sing
1 singing
3 sings
13 soft
1 softly
8 song
9 sound
22 speak
2 speech

1 spelling
1 steps
1 still
1 stormy
1 swallow
1 swear
1 sweet

130 talk
11 talking
1 teacher
1 there
1 tone
5 train

41 voice

1 walk
12 whistle
1 word

11 yell
1 yelled
1 you

84. THIEF

2 arrested

19 bad
1 be
1 beg
1 blue
1 boon
1 boot

1 fight
1 filled
1 food
1 fright
1 fun

2 girl
8 gold

1 lead
1 leaf
2 legs
2 liar
1 lie
1 light
2 locket
1 long

4 night
1 noisy

1 oats

2 police
6 prison

10 stealing
8 steals
28 stole
20 stolen
2 store
2 strong
3 suit

1	booster
1	bum
64	burglar
23	caught
1	chickens
1	cow
1	coward
2	dog
1	feet
1	good
11	gun
1	hat
1	he
3	hide
9	house
1	jail
4	kill
1	knife
1	mail
1	mamma
30	man
1	me
6	mean
1	meat
63	money
1	mouse
1	murder
1	nice
5	ring
21	rob
229	robber
4	robbers
6	robs
5	run
1	silverware
1	sold
1	sore
320	steal
10	stealer
9	take
1	theft
1	there
5	tramp
1	unkind
1	useful
1	wagon
1	walk
3	watch
1	white
1	women

85. LION

4	afraid
1	Africa
205	animal
3	anger
7	angry
1	awful
2	bad
1	bay
5	bear
95	beast
83	big
1	bind
18	bite
1	biter
1	bit
1	bones
1	boy
3	brave
1	bread
8	cage
1	cat
1	catch
1	cave
1	claws
1	close
4	creature
1	danger
1	David
1	deer
8	den
1	desert
1	dog
109	eat
3	eats
1	fear
1	feet
119	fierce
2	fight
1	fool
13	forest
1	fright
1	fur
5	good
7	growl
1	growling
5	growls
1	gun
1	have
2	hair
1	he
1	head
1	horse
1	huge
1	hunger
4	hungry
1	insect
16	jungle
1	jumps
15	kill
2	kills
27	king
16	large
3	legs
1	lift
3	live
1	long
14	mad
4	man
8	mane
1	many
7	mean
1	monster
1	mouse
5	mouth
1	prance
1	purr
52	roar
3	roars
3	rough
2	skin
1	small
1	story
1	string
16	strong
2	tail
1	tame
12	teeth
1	terrible
13	tiger
7	wild
8	woods
1	wool
1	yellow

86. JOY

3	army
3	automobile
3	baby
1	birth
6	boy
1	boys
3	bring
1	cake
1	cheer
2	child
2	children
45	Christmas
1	clap
1	comfortable
1	company
1	crazy
2	dance
1	doing
2	enjoy
1	father
1	feel
1	fest
4	fine
1	full
182	fun
3	funny
1	game
2	girl
203	glad
2	gladly
7	gladness
1	glee
2	going
27	good
1	ha ha
1	happily
25	happiness
260	happy
3	heart
6	home
1	honor
2	jokes
2	jolly
1	joyful
1	joys
1	jump
25	laugh
2	laughing
11	laughter
1	life
2	like
3	love
1	loving
4	man
3	merry
4	mother
1	naughty
1	new
28	nice
1	park
5	party
1	passed
1	piano
49	play
2	playful
1	playing
6	pleasure
1	pretty
1	rejoice
1	rejoicing
3	ride
2	riding
3	sad
1	sadness
1	school
1	show
1	skating
1	song
1	sorry
1	sprang
1	teeth
1	tickling
2	time
1	toy
1	train
1	trains
1	way
1	worry

87. BED

3	asleep
8	bedding
1	big
6	blanket
1	bought
1	brass
1	broke
1	buy
14	clothes
7	comfort
1	father
1	fell
1	fool
2	go
1	going
2	good
1	hard
1	head
1	home
2	laying
1	lazy
1	leg
1	legs
10	lie
1	like
1	little
1	lying
1	made
3	make
9	mattress
2	post
1	potatoes
8	quilt
17	rest
5	resting
8	room
1	rough
6	sheet
22	sick
39	soft
2	spread
4	springs
1	standing
6	supper
1	sweat
1	time
3	tired
1	to
10	warm

1 couch
12 cover
3 covers

2 down
4 dream

12 iron

1 keyhole

1 lady
109 lay

3 nice
106 night
4 nightgown

25 pillow

453 sleep
1 sleeper
16 sleeping
9 sleepy
6 slept
3 small

1 well
2 went
2 white
1 wooden

88. HEAVY

1 animal

3 baby
1 ball
1 barrel
4 bed
37 big
3 blocks
2 boards
4 book
12 box
6 boy
1 bundle
5 burden

1 can't
36 carry
1 case
6 chain
1 chair
1 cloth
6 coal
1 cover

1 desk

1 do
1 dog
2 doll
1 drop

1 engine
1 every

1 fall
1 fat
1 father
1 flour
1 full

3 gold
1 goods
1 guilt

5 hammer
178 hard
3 head
1 heaven
1 heft
3 house
1 hurt

213 iron
1 is
1 it

1 labor
22 large
2 lazy
35 lead
1 leaves
36 lift
5 lifting
54 light
1 little
72 load
2 loaded
1 loads
1 loan
1 log
1 look
1 lot
4 lumber
1 lunch

4 man

1 no

3 pail
1 paper
2 papers
2 potatoes
2 pound

1 quilt

1 rains
19 rock
1 rocks

1 sack
1 salt
1 sister
1 sledge
1 small
1 soft
1 steel
1 steep
1 stick
32 stone
1 stones

12 stove
20 strong
1 sunk

2 thick
1 thing
4 things
1 this
1 tight
5 tired
2 tiresome
1 too
1 tree
3 trunk

6 very

7 wagon
1 water
1 weak
1 weigh
39 weight
1 were
10 wood
1 work
1 world

89. TOBACCO

1 America
2 awful

7 bad
1 bag
6 bitter
1 blacksmith
6 box
8 brown

1 can
214 chew
7 chewing
2 cigar
4 cigarettes
5 cigars
1 climax

1 don't

1 eat

13 father

1 good
1 grew

1 habit
1 hard
1 harm
1 honor

1 Leader
2 leaf
7 leaves

3 like

28 man
10 men

3 nasty
1 naughty

2 opium

70 pipe
2 pipes
4 plant
5 plantation
1 pledge
1 pouch
3 poison

1 Prince Albert

2 raise
1 red
1 rug
1 ruin
1 ruins life

1 sick
1 slow
1 smith
466 smoke
3 smoked
1 smokers
2 smokes
28 smoking

18 snuff
1 so
20 spit
1 squeal
5 store
12 strong
1 sweet

1 use

1 Virginia

1 weeds

90. BABY

1 alive
3 asleep

1 bad
1 bakery
1 baptism
1 bare
1 bath
1 bed
1 big
1 birds
1 blanket
35 born
7 bottle
31 boy
1 brother
2 buggy

4 care
4 carriage

2 crib
1 cried
15 cries
119 cry
22 crying
14 cute

2 darling
4 dear
1 die
1 doctor
2 doll
1 dream
2 dress
1 drinks
1 drive

1 ears
1 ease
1 eat

9 girl
1 go
6 good
3 growing

1 hands
2 happy
1 have
1 hear
1 heel
1 helpless

20 infant
1 it

2 joy

1 kiss
1 kitten

3 lady

55 milk
22 mother

1 name
4 new
11 nice
1 nickel
21 night
1 nipple
1 nose
6 nurse
4 nursy

1 out

1 people
3 person
6 play
1 playing
5 pretty

1 school
3 sick
5 sister
20 sleep
90 small
1 smiled
1 soul
40 stork
11 sweet

14 tiny
2 toes
1 toys
1 tub

1 we
1 well
1 woman

1 young

172 child
17 cradle
3 crawl
2 crawling
3 creeps

9 eyes

3 face
1 fat
1 flesh

1 legs
97 little
4 love

1 Mabel

3 rattle
1 rock
1 running

1 youngling
1 youngster

91. MOON

1 above
1 at
1 away

1 baby
4 ball
29 big
115 bright

3 clear
2 cloud
8 cold
1 color
3 cow

10 dark

1 earth
3 evening

1 eyes

13 face
1 far
20 full

1 ghost
3 gold
1 gone
1 good

8 heaven
6 high
1 hood
2 house

4 lake
2 large
1 leave

1 led
155 light
1 little
1 loom
4 look
1 looks

6 man
1 moonlight
3 moves

7 nice
128 night
2 noon

1 person
3 pretty

1 quickly

1 red
5 rise
2 rising
101 round

1 see
1 setting
107 shine
26 shines
19 shining
1 shiny
1 show
2 silver
2 silvery
2 skies
103 sky
2 slow

1 small
1 soon
1 spoon
9 star
10 stars
1 still
6 summer
14 sun
1 sunlight
1 sunshiny

1 waxen
8 white
1 world

8 yellow

92. SCISSORS

1 article

1 bird
1 brass
1 broke
1 broken

1 cast
1 clip

32 cloth
1 clothes
1 coat
802 cut
3 cuts
1 cutter
48 cutting

1 dull

2 finger

1 glasses

1 have

1 knife

1 large

1 lizer
1 long

10 paper
2 papers

1 safety
1 screw
15 sew

11 sewing
35 sharp
8 shears
1 silk
1 silver
5 small
4 steel

1 waist
1 work

93. QUIET

1 alone
4 asleep
1 awful

14 baby
1 be
1 bed
13 boy

1 calm
1 cat
5 child
7 children
1 clean
1 cold
1 comfortable
1 country
1 cozy
1 creak

1 day
1 dark
1 dead
1 deserted

1 empty

1 feet
1 fight

11 girl
1 glass
20 good

3 hall
1 happy
1 hear
6 here
4 home
62 house

1 I
1 Indians

1 joy

1 keep

4 light

1 lightly
1 likes
13 listen
2 lonely
1 lonesome
11 loud
4 low

1 man
1 me
22 mice
1 mine
37 mouse
1 music

1 nap
1 napped
6 nice
55 night
70 noise
6 noiseless
18 noisy
1 now

3 old

1 peace
3 peaceful
1 person

3 quiet

4 reading
4 rest
3 resting
1 robber
1 rock
43 room

4 school
3 sick
5 silence
4 silent
1 sit
72 sleep
7 sleeping
22 sleepy
1 slept

3 slumber
1 small
1 smoke
46 soft
1 softly
1 solemn
14 sound
1 stepping
300 still
1 study

3 talk
1 thought

4 very

1 wake
1 whiskey
1 woman

1 you

94. GREEN

23 apple
7 apples

5 beautiful
1 beauty
1 bed
1 beet
1 big

1 cotton
2 country

12 dark
1 draw
100 dress
1 dummy
1 dye

15 hat
9 horn
9 house

1 ignorant
1 indolent
21 Irish
1 it

1 meadow
3 meadows

4 nice
1 night
1 nothing

19 paint

1 silky
4 skirt
1 slippers
1 small
1 sorrow
1 spire
1 spires
1 steam

1 blanket
13 blue
1 boat
3 book
1 boy
7 bright

1 cabbage
1 checkered
4 Christmas
12 cloth
5 coat
237 color
1 corn

1 fine
1 flag
7 flower
1 flowers
1 fresh
1 fruit

1 glass
1 good
3 goods
272 grass
1 gray
1 greenhouse

1 kind

1 lace
1 lavender
1 lawn
1 leaf
1 leafy
2 lean
13 leaves
13 light
2 like

1 man

9 paper
1 park
6 pencil
1 pink
8 plant
1 plume
23 pretty

1 railroad
4 red
6 ribbon

1 sad
15 silk

9 stem
1 style
1 sweet

1 thing
1 tree

29 waist
1 walls
3 white
1 wood
1 woods

6 yellow
1 young

95. SALT

4 bad
1 bake
1 beet
110 bitter
2 box
8 bread
1 bricks
4 burn
4 butter

1 carrot
1 cattle
3 cellar
1 China
1 class
6 cook
1 cooking
4 cow
1 cried
1 crystal

1 dandy
1 deep

1 doughnuts
1 dress
1 drink

93 eat
6 eating
1 egg
1 eggs

1 fall
1 feathers
1 fine
6 fish
4 flavor
5 food
1 found

1 goat
30 good
1 goods
1 grain

1 halt
1 horrid
1 horse

1 kitchen

1 lalt
2 lake
3 like
1 loft
1 look
1 love

1 malt
99 meat
1 me
1 men
3 mine
3 mineral
1 mountains
1 much

2 nasty
3 nice

64 ocean
1 onion

1 pain

29 pepper
3 petre
2 pickle
3 pinch
2 pork
5 potato
49 potatoes
1 pure
1 put

1 rabbit
1 roast
1 rock
1 rotten

1 sacks
10 salty
25 sea
1 shake
7 shaker
1 sharp
1 sheep
1 small
1 smart
1 soap

1 soft
4 soup
79 sour
1 stale
4 sting
3 store
13 strong
1 stuff
23 sugar
6 sweet
1 Syracuse

14 table
21 taste
1 tasty
10 thirsty
3 tomato
1 too

1 useful

1 we
60 water
97 white

96. STREET

1 Adams
2 alley
11 auto
1 autos
2 automobile
1 automobiles
34 avenue

1 beat
1 big
1 black
1 bled
2 block
1 blocks
1 blood
3 boys
4 brick
4 bricks
1 broad
1 Broadway
1 bumpy
3 busy

79 car
1 cars
2 cement
2 central

1 children
8 city
90 clean
12 cleaner
1 cleaning
1 complete
1 corners
4 country
4 crossing
15 curb

34 dirt
85 dirty
1 driving
1 dry
7 dust
7 dusty

1 earth
1 even

1 far
1 feet
1 funny

1 go
1 good

5 ground

1 Hennepin
1 home
42 horse
54 horses
4 house
1 houses

1 is

1 Jefferson

41 lamp
7 lamppost
1 land
3 large
1 lawn
1 light
3 lights
1 listen
7 live
13 long

4 man
1 marbles
1 Marshall

1 meat
2 meet
16 mud
15 muddy

3 narrow
1 newsboy
1 nice
1 noise
1 noisy
1 number

1 on
1 open
1 order
1 outdoors

1 pass
1 part
15 paved
15 pavement
3 paving
7 people
1 place
1 play
1 public

5 ride

60 road
1 rock
3 run
1 running

7 sand
2 sewer
23 sidewalk
2 slippery
2 stone
2 stores
1 straight
1 streetcar

1 teams
5 town
1 track

49 wagon
3 wagons
88 walk
1 walker
1 walking
5 walks
1 water
1 way
2 wet
8 wide

97. KING

2	America
1	animal
1	army
3	bad
1	beast
1	beautiful
3	beer
2	Belgium
1	big
2	boss
1	bow
1	brave
1	bring
1	brother
1	candy
5	castle
3	chief
1	Christ
2	citizen
3	city
1	clothes
1	cold
1	come
1	commander
83	country
3	court
1	crime
124	crown
4	crowned
3	cruel
4	Czar
1	dress
17	emperor
13	England
1	English
1	Europe
	fox
1	gentleman
1	George
1	George V
4	German
5	Germany
1	God
2	gold
25	good
2	governor
1	grand
1	habit
3	happy
1	Harold
1	have
4	head
1	hearts
1	high
1	hook
1	horse
1	hurt
1	ill
1	Ireland
1	island
1	judge
1	Kaiser
1	kill
18	kingdom
1	knights
[illegible]	[illegible]
1	lady
2	lame
29	land
1	ling
1	lion
1	majesty
66	man
1	manager
1	master
1	mayor
1	mean
1	men
1	money
1	my
1	nail
5	nice
2	noble
1	Norway
1	obey
1	old
1	own
1	owner
26	palace
2	person
1	Peter
1	pillory
1	place
1	Poland
1	poor
10	president
4	pretty
1	prince
1	princess
1	principal
1	proud
50	queen
2	reign
19	rich
1	robe
1	robes
1	royal
107	rule
1	ruled
170	ruler
4	rules
2	Russia
1	Russian
1	seat
1	servants
4	sit
1	small
3	soldier
5	soldiers
5	sovereign
1	staff
2	state
14	stick
1	Sultan
1	Sweden
1	sword
29	throne
1	trouble
1	very
5	walk
7	war
1	where
1	wine
1	wise
1	wood
3	world

98. CHEESE

1	bed-bugs
1	bees
2	bitter
1	bought
78	bread
22	brick
49	butter
6	cat
1	churn
8	cottage
3	cow
3	cows
1	cracker
33	cream
1	dinner
251	eat
4	eating
1	eats
1	Edam
1	egg
17	food
1	goat
1	goats
1	gone
57	good
1	grocer
[illegible]	[illegible]
1	holes
1	hungry
1	I
1	Italian
1	knees
1	knife
4	like
7	Limburger
1	lunch
1	man
1	meat
[illegible]	[illegible]
59	mice
32	milk
128	mouse
2	nice
1	old
1	pound
57	rat
32	rats
1	sandwich
13	smell
[illegible]	[illegible]
1	sneeze
2	soft
1	sour
3	stink
5	store
1	strong
1	supper
1	sweet
9	Swiss
1	Switzerland
1	taste
6	white
76	yellow

99. BLOSSOM

87	apple
7	apples
1	autumn
1	bears
1	beauty
2	big
1	bird
48	bloom
2	blooming
1	blooms
1	blue
45	bud
2	buds
1	California
1	cherry
1	clover
1	color
1	cook
1	crocus
1	earth
486	flower
93	flowers
1	fruit
8	garden
1	good
6	grow
[illegible]	[illegible]
1	hive
1	house
1	June
1	leaf
1	leaves
1	like
4	lily
1	love
1	May
1	nice
1	now
1	open
1	out
2	pansy
1	peach
1	peaches
1	peas
1	pick
4	pink
20	plum
37	pretty
1	purple
2	red
26	rose
1	roses
1	round
1	shiny
12	smell
11	spring
1	stem
14	summer
4	sweet
9	tree
1	tulip
1	violet
30	white
1	winter

100. AFRAID

1	alley
1	alone
1	am
3	animals
1	auto
18	baby
1	bad
1	bashful
3	bear
2	beast
10	boy
1	brand
4	brave
1	bright
1	bug
33	burglar
27	burglars
2	cat
3	children
1	cop
1	cow
19	coward
1	cry
1	crying
151	dark
73	dog
1	donkey
1	don't
14	fear
1	fire
1	foolish
6	fright
5	frighten
34	frightened
2	funny
15	ghost
1	ghosts
9	girl
1	glad
4	go
2	gun
1	gypsies
1	her
1	him
2	home
3	house
1	humor
1	jackal
22	lion
1	lonesome
1	long
1	maid
9	man
5	me
1	mean
1	melt
2	men
1	monkey
2	mouse
1	nervous
59	night
1	no
4	noise
1	people
1	pond
1	rabbit
1	rat
26	robber
2	robbers
22	run
41	scare
9	scarecrow
290	scared
1	scaring
1	scream
1	ship
2	sleep
1	snake
1	strong
1	tabby
1	that
8	thief
4	tiger
7	timid
1	very
3	walk
1	weary
4	wolf
1	women
1	word
1	yes
1	you

CHAPTER V

PREFERRED RESPONSES FOR DIFFERENT AGES

The preceding frequency tables, include, as already explained,[1] responses of children varying in age from 9 to 12. It seems desirable, therefore, to give some indication of the degree of agreement between the children of different ages. This is fairly well done by the table below, which gives separately for each age the three most frquent responses to each of the stimulus words. Since the 4 age-groups are not equal in numbers, the numerical frequencies of responses given by different groups could not be directly compared. We have, therefore, simply given the three most frequent responses in the order of their frequency, omitting the coefficients.

It will be seen that there is remarkably close agreement between children of the different ages. This is particularly striking when the present table is compared with a similar one for children as compared with adults, given in the following chapter. This agreement for the 4 different ages here in question is so close as to suggest that it would not be worth while to compile frequency tables for each age. Unless very large numbers of cases were used, something like ten thousand for each age, differences obtained with the different ages would scarcely be reliable. We believe, therefore, that we are justified in taking together, as one group, children of the 4 ages we have used, and regarding the results as representative of children in general between the ages 9 to 12 inclusive.

It may be pointed out, further, that the preceding tables may be much more correctly regarded as proper standards of association in children than can the Kent-Rosanoff tables as proper standards for adults, for the latter include responses from persons of from eight to over eighty years of age, though mainly of the adult ages. Kent and Rosanoff do not give the age distribution of their subjects, but they mention a group of 78 children under 16 years of age. On the whole, however, it is probably permissible to speak of their table as an adult table, as does Rosanoff himself.

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[1] See Chapter III, Composition of Groups.

PREFERRED RESPONSES BY AGES

Stimulus	9 yrs.	10 yrs.	11 yrs.	12 yrs.
1. Table	eat	eat	eat	eat
	legs	dishes	dishes	dishes
	dishes	legs	dish	legs
2. Dark	night	night	night	night
	black	black	see	see
	see	afraid	room	afraid
3. Music	piano	sing	piano	piano
	sing	piano	sing	sing
	play	sweet	play	sweet
4. Sickness	ill	doctor	bed	ill
	bed	bed	fever	doctor
	doctor	ill	doctor	bed
5. Man	work	hat	work	work
	hat	work	hat	hat
	rich	clothes	person	clothes
6. Deep	hole	hole	hole	hole
	water	water	well	water
	well	well	water	down
7. Soft	pillow	pillow	pillow	pillow
	nice	bed	cotton	bed
	cotton	cushion	bed	cotton
8. Eating	bread	bread	bread	bread
	table	table	table	food
	ice-cream	food	hungry	eat
9. Mountain	high	high	high	high
	hill	hill	hill	hill
	peak	snow	steep	snow
10. House	live	live	live	live
	room	warm	big	wood
	chair	room	warm	warm
11. Black	dark	dark	dark	dark
	dress	color	color	dirty
	color	dress	dress	color
14. Hand	clock	work	fingers	fingers
	fingers	fingers	work	finger
	work	clock	clock	work
15. Short	small	small	small	small
	little	little	little	little
	pencil	dress	walk	pencil
16. Fruit	apple	eat	apple	apples
	apples	orange	eat	eat
	eat	apple	good	banana
17. Butterfly	fly	fly	fly	fly
	pretty	wings	wings	wings
	bird	pretty	pretty	butter
18. Smooth	soft	soft	soft	soft
	flat	even	even	even
	ice	level	nice	rough
20. Chair	sit	sit	sit	sit
	seat	seat	seat	set
	legs	wood	set	rocking

21. Sweet	good	good	good	good
	candy	candy	sugar	sugar
	sugar	sugar	oranges	candy
22. Whistle	noise	blow	noise	blow
	blow	boy	blow	noise
	boy	noise	loud	loud
23. Woman	lady	lady	lady	lady
	dress	dress	dress	dress
	women	mother	mother	children
24. Cold	winter	ice	snow	winter
	freeze	winter	chilly	ice
	burn	snow	freeze	weather
25. Slow	walk	walk	lazy	fast
	lazy	lazy	walk	walk
	fast	clock	clock	lazy
26. Wish	bone	want	want	want
	want	fairy	bone	fairy
	doll	candy	dog	true
27. River	water	water	water	water
	lake	swim	swim	swim
	stream	lake	fish	fish
28. White	dress	dress	color	paper
	color	color	clean	light
	light	light	snow	color
29. Beautiful	pretty	pretty	pretty	pretty
	nice	nice	nice	nice
	dress	lady	lady	girl
30. Window	glass	glass	glass	glass
	pane	look	look	pane
	look	light	pane	look
31. Rough	hard	hard	hard	boy
	mean	bumpy	boy	mean
	bad	mean	board	smooth
33. Foot	walk	walk	walk	walks
	feet	toes	leg	walk
	leg	leg	toes	leg
34. Spider	web	web	web	legs
	legs	legs	legs	web
	bug	bug	bug	bug
35. Needle	sew	sew	sew	sew
	sewing	thread	stick	pin
	thread	sewing	sewing	sharp
36. Red	color	color	color	color
	bright	bright	dress	cloth
	dress	dress	bright	bright
37. Sleep	bed	bed	bed	bed
	night	night	night	night
	tired	eyes	tired	dream
38. Anger	mad	mad	mad	mad
	fight	mean	fight	fight
	cross	cross	cross	scold
39. Carpet	rug	rug	rug	rug
	floor	floor	floor	floor
	sweep	dirty	walk	house
40. Girl	dress	dress	dress	dress
	boy	nice	child	child
	hair	doll	big	boy
41. High	mountain	mountain	hill	mountain
	air	tall	up	up
	far	hill	mountain	hill

42. Working	hard	hard	hard	hard
	busy	man	man	man
	man	men	men	busy
43. Sour	milk	pickles	milk	sweet
	cream	milk	bitter	eat
	sweet	vinegar	lemon	bitter
44. Earth	ground	ground	ground	ground
	round	dirt	dirt	round
	black	round	black	dirt
46. Soldier	war	war	war	man
	fight	fight	fight	fight
	fighting	man	army	war
47. Cabbage	eat	vegetable	vegetable	eat
	vegetable	eat	eat	vegetable
	garden	garden	leaves	leaves
48. Hard	stone	stone	stone	work
	work	rock	work	floor
	rock	floor	soft	rock
49. Eagle	bird	bird	bird	bird
	fly	fly	fly	fly
	big	wings	mountain	wings
50. Stomach	ache	ache	ache	eat
	eat	body	sick	ache
	food	eat	eat	sick
51. Stem	flower	flower	flower	flower
	cut	long	flowers	flowers
	green	flowers	long	long
52. Lamp	light	light	light	light
	burn	burn	glass	glass
	glass	glass	burn	burn
53. Dream	sleep	sleep	sleep	sleep
	night	night	night	night
	bed	bed	bed	bed
54. Yellow	color	color	color	color
	dress	dress	dress	dress
	flower	flower	flower	light
55. Bread	eat	eat	eat	eat
	dough	flour	good	flour
	butter	good	flour	dough
57. Boy	play	play	pants	play
	ball	man	cap	man
	bad	pants	child	girl
58. Light	lamp	lamp	lamp	dark
	dark	dark	day	day
	bright	gas	bright	lamp
60. Bible	book	book	book	God
	church	God	read	book
	holy	read	church	read
62. Sheep	wool	wool	wool	wool
	animal	animal	animal	animal
	lamb	white	lamb	white
63. Bath	water	water	water	water
	clean	wash	wash	clean
	tub	clean	clean	wash
64. Cottage	house	house	house	house
	lake	home	home	home
	live	lake	lake	lake
65. Swift	fast	fast	fast	fast
	run	run	run	horse
	horse	horse	horse	run

66. Blue	color dress flag	color dress sky	color dress sky	color dress sky
67. Hungry	eat bread food	eat bread food	eat bread starve	eat bread starve
68. Priest	church minister Catholic	church minister Catholic	church minister Catholic	church minister man
69. Ocean	water waves river	water sea river	water waves sea	water sea ships
70. Head	hair brains eyes	hair brains round	hair brains eyes	hair eyes brains
71. Stove	fire hot warm	hot fire warm	hot fire warm	fire heat hot
72. Long	grass big stick	far grass big	grass far dress	short far grass
74. Whiskey	drink beer drunk	drink drunk liquor	drink drunk beer	drink drunk beer
75. Child	baby good girl	baby girl boy	baby children girl	baby boy children
77. Hammer	pound nail nails	pound nail nails	pound nail nails	nail nails pound
78. Thirsty	water drink dry	drink water dry	water drink dry	water drink dry
79. City	Minneapolis country town	Minneapolis big town	Minneapolis big town	Minneapolis town big
80. Square	block box oblong	block box corner	block oblong straight	block oblong corner
81. Butter	bread yellow eat	bread yellow eat	bread yellow eat	bread eat yellow
82. Doctor	sick man medicine	sick medicine man	sick man medicine	sick medicine man
83. Loud	holler talk noise	noise holler talk	noise talk holler	holler noise talk
84. Thief	steal robber money	steal robber burglar	steal robber money	steal robber burglar
85. Lion	animal beast eat	animal beast fierce	animal eat fierce	animal fierce eat
86. Joy	happy fun glad	happy glad fun	happy glad fun	happy fun glad
87. Bed	sleep lay night	sleep lay night	sleep night lay	sleep night lay

88. Heavy	**iron hard load**	**hard iron load**	**hard iron load**	**light hard iron**
89. Tobacco	**smoke chew pipe**	**smoke chew pipe**	**smoke chew pipe**	**smoke chew pipe**
90. Baby	**child little cry**	**child cry small**	**child cry little**	**cry child little**
91. Moon	**night round bright**	**light bright night**	**light shine round**	**light night bright**
92. Scissors	**cut cutting sharp**	**cut cutting sharp**	**cut cutting sharp**	**cut cutting cloth**
93. Quiet	**still sleep soft**	**still noise sleep**	**still sleep house**	**still house noise**
94. Green	**grass color dress**	**color grass dress**	**grass color dress**	**color grass dress**
95. Salt	**bitter white meat**	**bitter white meat**	**eat meat bitter**	**meat bitter eat**
96. Street	**dirty clean horse**	**walk dirty car**	**walk dirty road**	**walk car dirty**
97. King	**crown ruler good**	**crown ruler rule**	**ruler crown country**	**ruler rule country**
98. Cheese	**eat mouse rat**	**eat mouse bread**	**eat mouse butter**	**eat mouse yellow**
99. Blossom	**flower flowers apple**	**flower flowers apple**	**flower flowers apple**	**flower flowers white**
100. Afraid	**scared dark night**	**scared dark dog**	**scared dark dog**	**scared dark night**

CHAPTER VI

COMPARISON OF ASSOCIATION TYPES OF CHILDREN AND ADULTS

Nearly every writer on the psychology of association has emphasized the difficulties of any classification of associations according to their form, or type. With respect to these difficulties, we agree absolutely with previous workers. We do not wish to minimize the uncertainty and arbitrariness of any classification of associations, particularly when unaided by introspection; nor do we claim any value, except for our present purpose, for the system of headings which we ourselves have used. As regards the aid to be obtained from introspection, it may be questioned if children's introspection would be of sufficient reliability for use in the classification of associations according to their type. At any rate, introspections were not available, either for children or adults.

Notwithstanding the difficulties, we believe that the careful classification of associations that we have made for both children and adults is of great value. In spite of the large numbers of possible errors, the comparison of these classifications brings out in unquestionable manner a number of extremely striking and important differences in the mental processes of children and adults.

In this connection, we should like to quote, approvingly, Kent and Rosanoff: "It must, indeed, be conceded that objective methods can reveal but indirectly and with uncertainty the inner mechanism which produces any association and that in any given instance it would be impossible to establish the correctness of grouping in accordance with such methods. However, to decide that question for any given reaction is really not necessary in practice, since an error made through wrongly placing one, two, or three reactions under any heading is of no significance; the types acquire importance when represented by large numbers . . . and when many reactions fall under a single heading the likelihood of error, as affecting the record as a whole, is by that fact alone greatly reduced.

"The whole question might more profitably be approached from another point of view. To what extent are the distinctions of this classification useful? An answer to this question can be found only in the results."[1] It should be explained that the above statements of Kent and Rosanoff were made concerning their system of classification and not the one we have used, but they express our attitude towards our own attempts at classification.

As regards the value of classifications as significant forms of description, we agree with Wells, who writes as follows: "In the valuable study of Kent and Rosanoff, considerable distrust is expressed of the quasi-logical categories, because of their vagueness and subjectivity. A somewhat similar opinion has been expressed by the present writer. At the same time, it could obviously not be supposed that the further development of the association test would render it possible to dispense altogether with this principle of classification. It is as impracticable to make frequency tables for all association words as it is desirable to state their results in a more significantly descriptive form than they permit."[2]

In our selection of classificatory categories, we have endeavored merely to get headings which would serve to descrie the chief similarities and dissimilarities between the associations of children and adults. We have distinguished the following types:

I. Superordination
II. Subordination
III. Coordination
IV. Contrast
V. Similarity
VI. Part-Whole
VII. Whole-Part
VIII. Cause-Effect
IX. Effect-Cause
X. Material
XI. Contiguity
XII. Verbs
XIII. Participles
XIV. Adjective-Noun
XV. Noun-Adjective
XVI. Noun-Abstract Attribute
XVII. Verb-Object
XVIII. Pronouns
XIX. Sound-Similarity
XX. Word-Compounding
XXI. Non-Specific
XXII. Miscellaneous

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[1] *Op. cit.*, pp. 27-28.

[2] A Preliminary Note on the Categories of Association Reactions,' *Psych. Rev.* Vol. XVIII, 1911, p. 229.

The meaning of most of these headings is sufficiently clear, particularly as they are fully illustrated further on. Some of them, however, require a few words of explanation. The class of associations headed contiguity, includes associations by both temporal and spatial contiguity. Associations by temporal contiguity were so rare that it did not seem worth while to make a separate class of them. This class includes also any response which might be designated a spatial or temporal localization. We have also placed in this class, instead of under whole-part, any association between a person and an article of clothing.

The distinction between the classes *verbs* and *participles* is an important one, as the participles, particularly the present ones, which almost exclusively compose this class, usually have a more abstract implication than the verbs.

Under the heading, word-compounding, we have included not only cases of actual compounding but all pairs of words so closely connected as practically to form a compound word, such as high,—up and deep,—down. Under this same heading, we have placed all cases of syntactical change, except those which are classified under the heading of sound-similarity. Thus the association long,—length is classified under word-compounding and high,—height under sound similarity. This inclusion of certain cases of syntactical change under the heading of word-compounding makes the heading somewhat misleading. Perhaps 'superficial verbal' would be a better heading, in which case, association by sound similarity would be a sub-class.

The miscellaneous group includes three cases: first, associations which seemed to belong fairly well in more than one of our groups; second, associations of a sort so rare that it was not deemed worth while to make a separate classification of them; and third, associations which were extremely difficult to classify at all, at any rate, under any very general heading.

The responses classed as non-specific, no matter with what stimulus words they occurred, were the following:

article(s)
bad
beautiful
beauty
big
fine
good
happy
happiness
large
man
nice
object
people
person
pleasant
pleasantness
pleasing
pleasure
pretty
small
thinking
thought(s)
unnecessary
unpleasant
use(s)
used
useful(ness)
useless(ness)
using
woman
work

Using the data on the ninety words which both our tables and the Kent-Rosanoff tables have in common, we have classified, with the greatest care every response in both the children's tables and the Kent-Rosanoff tables with a frequency of ten or over. For three of our classes of associations, we have classified every case, even those of a frequency of only one. These classes are the associations by similarity in sound, responses consisting of pronouns and the non-specific responses. With these classes, especially the first two of them, such a large proportion of the responses have a frequency less than ten that representative results could hardly be secured without using all cases. No response has been classified under more than one heading, with the exception of the non-specific responses. All the non-specific responses, however, are classified twice,—once under the heading of non-specific and once under some other heading.

In our tabulated summary of the various association types, we have used all the associations that we have classified. In the table, we give for each type of association, for children and adults separately, the following: first, the number of response words of the type in question (No.); 2d, their average frequency (Av. F.); third, the sum of their frequencies (Total); and fourth, the percentage of all the responses composed by the responses of the type in question, that is the percentage that the total frequency is of 90,000 (%).

SUMMARY OF DATA ON ASSOCIATION TYPES

	Adults				Children			
Class	No.	Av.F.	Total	%	No.	Av.F.	Total	%
Superordination	97	70	6,832	7.6	61	54	3,304	3.7
Subordination	45	33	1,478	1.6	43	44	1,912	2.1
Coordination	253	39	9,781	10.9	207	26	5,442	6.0
Contrast	66	144	9,500	10.6	50	24	1,201	1.3
Similarity	147	54	7,978	8.9	115	67	7,729	8.6
Part-Whole	19	52	997	1.1	15	22	337	0.4
Whole-Part	63	30	1,903	2.1	63	52	3,248	3.6
Cause-Effect	41	54	2,213	2.5	30	58	1,741	1.9
Effect-Cause	13	26	338	0.4	11	43	471	0.5
Material	20	44	878	1.0	19	43	812	0.9
Contiguity	172	31	5,372	6.0	210	66	13,763	15.3
Verbs	175	33	5,776	6.4	192	48	9,163	10.2
Participles	63	28	1,738	1.9	53	15	803	0.9
Adj.-Noun	273	23	6,204	6.9	291	35	10,077	11.2
Noun-Adj.	221	17	3,851	4.3	230	31	7,037	7.8
Noun-Abst. Att. ...	12	21	248	0.25	6	7	44	0.05
Verb-Object	28	27	764	0.9	33	45	1,488	1.7
Pronouns	30	2	51	0.05	104	2	202	0.22
Sound Similarity.....	29	2	61	0.07	133	3	384	0.43
Word-Compounding	25	28	697	0.77	27	35	942	1.04
Non-Specific	603	9	5,614	6.2	563	12	6,904	7.7
Miscellaneous	81	53	4,251	4.7	73	68	4,998	5.5

The data presented in the table admit of a number of conclusions, which, so long as they are stated in a non-mathematical manner, may be regarded as established beyond a doubt. These conclusions are the following:

(1) The following types occur more frequently in children than adults: verbs, verb-object, noun-adjective, adjective-noun, pronouns, sound similarity, contiguity, whole-part and, less definitely, subordination and word-compounding.

(2) The following types occur more frequently in adults than in children: contrast, superordination, coordination, part-whole, noun-abstract attribute, participles and, less definitely, cause and effect.

(3) The following types are about equally frequent in both pronouns, sound similarity, contiguity, whole-part and, less def- reactions belonging to the miscellaneous group, and effect-cause. The results with respect to associations from effect to cause, however, we regard an unreliable for not only is the number of such cases small, but are nat very clear-cut cases.

The preceding conclusions are based upon the results obtained with a particular list of stimulus words. To what extent this fact limits their general validity, it is hard to say. Differences between groups would, however, be much less dependent upon the list of stimulus words than would the relative frequency of the various types of association for a single group. For example, it presumably matters but little whether our list contains ten or thirty stimulus words with easy opposites. So long as we give the same words to both children and adults, we are justified in comparing them with respect to their tendency to give opposites.

We should like very much to print our classifications in full, but this would require too much space. We have decided, therefore, to limit our printed classifications to responses possessing a frequency of fifty or over in one or the other of the tables. These are sufficient in number to show how we have interpreted our various classificatory categories, and they illustrate fairly well the differences or similarities, as the case may be, existing between children and adults with respect to the various types.

In comparing the frequencies of response of adults and children in any one case, a number of complicating conditions should be kept in mind.

In the first place, the frequency of any single response of a given type may be lowered because of the high frequency of a response of a different type. For example, let us suppose that adults have a stronger tendency than children towards association by superordination, and at the same time a stronger tendency towards association by contrast. Now if the stimulus word is one which has an easy opposite, a very large portion of the adults' responses may consist of this opposite. Consequently, there will be fewer adult responses left to be divided among the other reaction words; and the frequency of a given superordinating response may be less with the adults than with the children, in spite of a greater tendency towards superordination on the part of the adults, simply because a greater portion of the adult responses have been used up in the contrasting response.

Again, the difference in vocabulary between adults and children has to be carefully considered. Without at present raising the general question of the explanation of the differences in association type between adults and children, it is evident that many responses (such as the response *abode*, to *house*) can not be expected from children, simply because they have not acquired them. Now it may happen in some cases that most of the fitting responses of a given association type are words which children have not at their command, in which case the frequency of the children's responses of this type would naturally be low, even though in general their tendency towards associations of this type might be high.

On the other hand, the adults may know several response words of a certain type and give all of them, whereas the children might know only one. In this case the frequency attaching to the children's single response might be greater than that attaching to the adults', simply because the children had united on the one word; and yet the general tendency of the adults towards the type of association in question might be much more pronounced than that of children.

Another point that should be considered, one of great importance, is the definiteness or accuracy with which a response shows the type of association in question. For example, the association, cabbage,—vegetable, is a much more clear cut case of super-ordination than the association, cabbage,—thing. In general it may be said that the non-specific responses,—responses, that is, which occur to many different stimulus words, are less significant than specific responses. A number of the exceptions to the general trend of differences between adults and children occur in connection with these non-specific responses. For example, the adults show a distinctly greater tendency towards superordination than the children, and yet the frequency for children is slightly greater in three of the cases where non-specific responses occur, namely, man,—person, woman,—person, and boy,—person. Similarly, in cases where the classification of an association is doubtful, differences in the frequency of that association between adults and children must be of more doubtful significance, as regards preferred types of association, than where the classification is unquestionably correct.

Lastly, one should keep in mind the unreliability of any particular frequency. Whenever the differences between the frequencies for adults and for children is small, it is not certain but that the group showing the highest frequency would not, with a larger number of subjects, show the lower frequency.

We append the classifications of responses of a frequency of fifty or over.

CLASSIFICATIONS OF ASSOCIATIONS

I. SUPERORDINATION

Stimulus	Response	Adults	Children
1. Table	furniture	75	0
3. Music	sound	95	35
5. Man	male	99	8
10. House	building	78	16
	dwelling	68	1
	home	103	39
17. Butterfly	insect	261	66
20. Chair	furniture	83	7
22. Whistle	noise	173	185
23. Woman	female	134	9
27. River	stream	117	30
34. Spider	bug	58	83
	insect	276	57
39. Carpet	covering	76	0
40. Girl	child(ren)	51	57
	female	77	22
46. Soldier	man	189	95
47. Cabbage	vegetable(s)	404	174

Stimulus	Response	Adults	Children
49. Eagle	bird	568	373
50. Stomach	organ	81	0
55. Bread	food	191	37
57. Boy	child(ren)	87	59
	male	63	9
60. Bible	book	338	224
62. Sheep	animal(s)	243	119
64. Cottage	home	85	101
68. Priest	man	75	69
74. Whiskey	liquor	70	97
77. Hammer	tool	69	11
81. Butter	food	63	19
82. Doctor	man	68	132
85. Lion	animal	326	205
	beast	67	95
97. King	man	43	66
98. Cheese	food	91	17

II. SUBORDINATION

Stimulus	Response	Adults	Children
3. Music	piano	180	198
	song(s)	74	66
4. Sickness	fever	9	50
16. Fruit	apple(s)	259	305
	banana(s)	19	96
	orange(s)	45	99
23. Woman	mother	30	53
44. Earth	clay	71	0
75. Child	boy	64	90
	girl	45	93
79. City	Minneapolis	0	218
	New York	99	2
99. Blossom	apple	50	87

III. COORDINATION

Stimulus	Response	Adults	Children
1. Table	chair(s)	274	24
5. Man	boy	44	29
6. Deep	low	51	35
10. House	barn	74	12
14. Hand	foot	204	0
16. Fruit	vegetable(s)	103	13
17. Butterfly	bird(s)	74	57
18. Smooth	nice	4	68
	soft	79	132
20. Chair	table	191	29
21. Sweet	good	26	213
23. Woman	girl	59	17
25. Slow	easy	63	13
	lazy	28	138
27. River	lake	65	42
29. Beautiful	nice	73	169
30. Window	door	57	2
31. Rough	hard	38	144
	mean	1	71
33. Foot	hand	185	5
34. Spider	fly	136	40
35. Needle	pin(s)	158	37
36. Red	black	61	0
	blue	99	9
	white	97	18
40. Girl	woman	61	8
41. High	far	1	58
43. Sour	bitter	70	63
46. Soldier	sailor	58	0
50. Stomach	intestine(s)	60	1
51. Stem	flower(s)	266	447
	leaf	96	11
53. Dream	thought(s)	60	4
54. Yellow	white	70	5
57. Boy	man	104	61
60. Bible	church	50	110
62. Sheep	lamb(s)	187	108
66. Blue	green	54	1
	red	54	21
67. Hungry	thirsty	73	14
69. Ocean	sea	75	88

Stimulus	Response	Adults	Children
70. Head	foot	64	0
72. Long	big	1	55
74. Whiskey	alcohol	50	15
	beer	46	108
75. Child	baby	193	185
	infant	122	3
	mother	55	26
79. City	country	74	86
	town	258	110
80. Square	oblong	32	95
81. Butter	milk	101	47
85. Lion	tiger	102	13
88. Heavy	hard	38	178
90. Baby	child	239	172
91. Moon	sun	120	14
	star(s)	125	19
92. Scissors	knife	66	2
93. Quiet	peaceful	52	3
	rest	68	4
94. Green	yellow	54	6
95. Salt	bitter	40	110
	pepper	142	29
	sour	18	79
	sugar	88	23
96. Street	avenue	63	34
	road	91	60
98. Cheese	bread	56	78
	butter	136	49
	milk	106	32

IV. Contrast

2. Dark	light	427	38
4. Sickness	health	142	6
5. Man	woman(en)	394	25
6. Deep	shallow	180	6
7. Soft	hard	365	27
9. Mountain	valley	90	3
11. Black	white	339	27
15. Short	long	279	54
	tall	168	12
18. Smooth	rough	277	35
21. Sweet	bitter	50	0
	sour	301	23
23. Woman	man	292	17
24. Cold	hot	151	12
	warm	166	25
25. Slow	fast	316	65
	quick	56	4
28. White	black	308	28
29. Beautiful	ugly	66	0
31. Rough	smooth	346	35
37. Sleep	awake	94	14
	wake	60	6
40. Girl	boy	350	40
41. High	low	328	25
43. Sour	sweet	349	75
48. Hard	soft	367	65
57. Boy	girl	319	32
58. Light	dark	231	99
	darkness	93	0
65. Swift	slow	190	28
72. Long	short	413	45
80. Square	round	250	35
83. Loud	low	57	8
	soft	165	13
86. Joy	sorrow	135	0
88. Heavy	light	273	54
93. Quiet	noise	50	70
	noisy	113	8
97. King	queen	354	50

V. Similarity

2. Dark	black	76	80
4. Sickness	ill(ness)	119	100
9. Mountain	hill(s)	216	97
11. Black	dark	172	315
15. Short	little	15	157

Stimulus	Response	Adults	Children
	small	136	214
18. Smooth	even	30	70
	level	52	55
20. Chair	seat	127	131
23. Woman	lady	41	243
26. Wish	desire	197	4
28. White	clean	10	97
29. Beautiful	handsome	86	13
	lovely	64	8
	pretty	113	280
31. Rough	bumpy	1	61
38. Anger	cross	44	56
	passion	51	0
	temper	149	8
	wrath	52	0
39. Carpet	rug(s)	177	247
41. High	tall	57	56
42. Working	busy	51	49
	labor	147	18
44. Earth	dirt	115	102
	ground	166	223
58. Light	bright	47	74
62. Sheep	mutton	60	9
64. Cottage	house	461	425
65. Swift	fast	222	391
	quick	117	10
68. Priest	clergyman	62	0
	minister	178	168
	preacher	35	57
72. Long	far	8	90
78. Thirsty	dry	218	132
81. Butter	grease	76	5
82. Doctor	physician	213	6
83. Loud	noisy	112	11
84. Thief	burglar	118	64
	robber	126	229
86. Joy	fun	6	182
	glad	27	203
	happiness	215	25
	happy	71	260
	pleasure	121	6
90. Baby	infant	168	20
93. Quiet	still	136	300
97. King	ruler	162	170
99. Blossom	flower(s)	540	579
100. Afraid	nervous	55	1
	scared	106	290
	timid	55	7
	VI. PART-WHOLE		
16. Fruit	tree(s)	62	11
33. Foot	limb	58	0
46. Soldier	army	137	63
50. Stomach	body	99	78
51. Stem	plant	74	25
70. Head	body	146	26
99. Blossom	tree(s)	57	9
	VII. WHOLE-PART		
1. Table	leg(s)	23	78
3. Music	notes	17	10
9. Mountain	peak(s)	17	50
	rock(s)	18	49
10. House	room(s)	17	64
14. Hand	finger(s)	112	199
17. Butterfly	wing(s)	41	137
30. Window	glass	316	421
	pane	82	62
33. Foot	toe(s)	71	115
34. Spider	legs	27	107
47. Cabbage	leaves	11	62
49. Eagle	wing(s)	24	92
62. Sheep	wool	143	411
69. Ocean	wave(s)	57	96
70. Head	brain(s)	90	162
	eye(s)	12	107
	hair	159	203
79. City	house(s)	55	29

VIII. CAUSE-EFFECT

Stimulus	Response	Adults	Children
4. Sickness	death	115	8
52. Lamp	light	650	648
63. Bath	clean	120	192
	cleanliness	109	1
71. Stove	fire	217	164
	heat	213	112
74. Whiskey	drunk	31	138
91. Moon	light	231	155

IX. EFFECT-CAUSE

37. Sleep	tired	26	67
67. Hungry	appetite	57	3
100. Afraid	burglar(s)	5	60
	dark	114	151
	dog	1	73

X. MATERIAL

2. Table	wood	76	21
35. Needle	steel	53	23
52. Lamp	glass	8	50
55. Bread	dough	26	80
	flour	88	95
36. Bath	water	339	295
77. Hammer	iron	45	62

XI. CONTIGUITY

1. Table	dish(es)	45	159
2. Dark	night	221	421
4. Sickness	bed	54	105
	doctor	62	116
5. Man	hat	7	82
8. Eating	table	21	108
9. Mountain	snow	10	61
14. Hand	arm	63	44
30. Window	light	186	47
33. Foot	leg(s)	55	115
	shoe(s)	163	81
35. Needle	thread	160	72
37. Sleep	bed(s)	75	382
	night	49	95
38. Anger	boy(s)	3	53
39. Carpet	floor	256	149
40. Girl	dress	8	240
46. Soldier	gun	27	61
50. Stomach	food	102	83
51. Stem	pipe	70	42
53. Dream	bed	11	78
	night	42	260
54. Bread	butter	151	8
57. Boy	ball	10	55
	cap	1	53
	pants	6	63
58. Light	day	81	67
64. Cottage	lake	5	117
68. Priest	church	166	271
69. Ocean	boat(s)	7	54
	ship(s)	35	79
74. Whiskey	saloon	15	57
81. Butter	bread	206	467
82. Doctor	medicine	149	136
	sick	52	448
	sickness	104	34
84. Thief	money	16	63
87. Bed	night	11	106
89. Tobacco	pipe	69	70
90. Baby	milk	1	55
91. Moon	night	66	128
	sky	73	103
	stars	93	10
96. Street	horse(s)	2	96
97. King	crown	13	124
	country	63	83
98. Cheese	mice	25	59
	mouse	13	128
	rat(s)	15	89

XII. Verbs

Stimulus	Response	Adults	Children
1. Table	eat	63	358
2. Dark	see	0	47
3. Music	play	7	81
	sing	12	153
5. Man	work	17	168
8. Eating	eat	0	51
9. Mountain	climb	9	29
10. House	live	33	165
14. Hand	work	49	113
	write	3	52
16. Fruit	eat	62	153
17. Butterfly	fly	44	179
20. Chair	sit	107	430
22. Whistle	blow	95	189
	sing	75	6
24. Cold	freeze	7	68
25. Slow	walk	8	107
26. Wish	hope	51	10
	want	66	99
27. River	swim	4	72
30. Window	look	15	116
33. Foot	walk	106	205
34. Spider	crawls	1	54
35. Needle	sew	134	449
37. Sleep	dream	28	55
	rest	300	40
	wake	60	6
38. Anger	fight	8	57
39. Carpet	walk	15	88
43. Sour	eat	0	54
46. Soldier	fight	17	160
47. Cabbage	eat	30	193
49. Eagle	fly	46	120
50. Stomach	ache	31	189
	eat	45	108
52. Lamp	burn	20	70
53. Dream	sleep	339	272
55. Bread	eat	148	356
57. Boy	play	20	84
60. Bible	read	31	116
63. Bath	wash	102	143
64. Cottage	live	17	79
65. Swift	run	19	202
67. Hungry	eat	126	337
70. Head	think	9	59
71. Stove	burn	12	103
	cook	24	62
74. Whiskey	drink	232	279
77. Hammer	pound	51	288
78. Thirsty	drink	206	364
79. City	live	7	50
81. Butter	eat	34	122
83. Loud	holler	16	190
84. Thief	steal	212	320
85. Lion	eat	1	109
	roar	46	52
87. Bed	lay	8	109
	rest	132	17
	sleep	345	453
89. Tobacco	chew	28	214
	smoke	387	466
90. Baby	cry	37	119
91. Moon	shine	26	107
92. Scissors	cut	347	802
96. Street	walk	78	88
97. King	rule	10	107
98. Cheese	eat	67	251
100. Afraid	fear	197	14

XIII. Participles

Stimulus	Response	Adults	Children
3. Music	singing	48	23
8. Eating	drinking	166	2
20. Chair	sitting	56	17
35. Needle	sewing	107	81
67. Hungry	eating	64	5
84. Thief	stealing	69	10
89. Tobacco	smoking	98	28
92. Scissors	cutting	114	48

XIV. Adjective-Noun.

Stimulus	Response	Adults	Children
6. Deep	hole	32	257
	ocean	93	15
	sea	90	14
	water	134	145
	well	44	87
7. Soft	bed	12	57
	bread	4	45
	cotton	28	57
	cushion	25	39
	pillow	53	138
11. Black	dress	29	63
	night	51	15
18. Smooth	glass	56	48
21. Sweet	apple(s)	14	66
	candy	82	146
	sugar	224	178
24. Cold	ice	114	84
	snow	45	62
	winter	120	103
25. Slow	snail	62	2
28. White	cloth	17	61
	dress	34	149
	light	51	125
	paper	17	54
	snow	91	65
29. Beautiful	flower(s)	55	43
31. Rough	boy(s)	8	126
36. Red	apple(s)	16	56
	blood	71	14
	cloth	8	65
	dress	18	85
41. High	air	5	50
	hill	20	92
	mountain(s)	173	125
42. Wbrking	man	1	93
	men	0	52
43. Sour	apple(s)	37	96
	cream	0	52
	lemon(s)	95	60
	milk	31	124
	pickle(s)	41	110
	vinegar	91	53
48. Hard	floor	16	54
	ground	2	51
	rock	38	92
	stone	102	113
	wood	66	30
	work	19	89
54. Yellow	dress	9	129
	flower	38	105
	light	14	59
	orange	47	81
65. Swift	horse	28	124
66. Blue	dress	18	173
	flag	6	82
	sky	239	102
72. Long	distance	81	6
	grass	4	75
80. Square	box	36	80
	corner(s)	25	89
83. Loud	noise	205	201
	talk	12	130
88. Heavy	iron	70	213
	lead	60	35
	load	57	72
	weight	177	39
93. Quiet	house	3	62
94. Green	dress	6	100
	grass	284	2
95. Salt	meat	18	99
	water	34	60

XV. NOUN-ADJECTIVE

Stimulus	Response	Adults	Children
3. Music	sweet	47	79
5. Man	big	0	26
9. Mountain	high	246	390
10. House	big	4	51
	warm	3	62
16. Fruit	good	24	89
17. Butterfly	pretty	39	89
22. Whistle	loud	27	71
35. Needle	sharp	152	56
36. Red	bright	40	68
39. Carpet	soft	78	28
44. Earth	black	7	73
	round	61	82
46. Soldier	brave	46	53
49. Eagle	big	0	52
50. Stomach	sick	10	85
51. Stem	long	18	60
55. Bread	good	21	90
60. Bible	holy	57	68
62. Sheep	white	18	57
68. Priest	Catholic	36	111
69. Ocean	deep	87	23
70. Head	round	21	58
71. Stove	black	59	37
	hot	86	200
	warm	32	127
75. Child	good	7	78
	small	52	45
79. City	big	9	124
	large	62	40
81. Butter	soft	65	8
	yellow	80	117
85. Lion	big	2	83
	fierce	36	119
90. Baby	little	12	97
	small	42	90
91. Moon	bright	52	115
	round	33	101
92. Scissors	sharp	190	35
95. Salt	white	36	97
96. Street	clean	7	90
	dirty	5	85
	long	29	13
	narrow	21	3
98. Cheese	good	15	57
	yellow	32	76

XVII. VERB-OBJECT.

8. Eating	bread	46	178
	food	170	54
26. Wish	fairy	11	64
77. Hammer	nail(s)	283	404

XX. WORD-COMPOUNDING

1. Table	cloth	57	43
26. Wish	bone	19	85
34. Spider	web	188	261
41. High	up	26	60
63. Bath	tub	71	131
72. Long	length	50	25
96. Street	car(s)	18	80

XXII. MISCELLANEOUS

11. Black	color	129	104
14. Hand	clock	1	65
21. Sweet	taste	57	23
22. Whistle	boy(s)	61	103
27. River	water	393	433
28. White	color	170	116
36. Red	color	254	298
38. Anger	cross	44	56
	mad	121	471
	mean	1	53
42. Working	hard	105	299

Stimulus	Response	Adults	Children
43. Sour	taste	55	28
46. Soldier	war	94	203
50. Stomach	digestion	50	1
54. Yellow	color	301	320
58. Light	gas	21	64
	lamp	82	251
	sun	85	29
60. Bible	God	43	124
	religion	89	4
66. Blue	color	256	318
67. Hungry	bread	26	173
	food	136	55
69. Ocean	water	427	413
77. Hammer	hard	53	20
78. Thirsty	water	341	377
80. Square	block	71	300
89. Tobacco	habit	94	1
93. Quiet	sleep	24	72
94. Green	color	200	237
95. Salt	taste	87	21
100. Afraid	coward	53	19
	night	12	59

Classes XVI, XVIII, XIX and XXI have been omitted from the proceding tables. Under the heading noun-abstract attribute (class XVI), there was only one association of a frequency of over 50 with either adults or children, the association, mountain,—height (adults, 73, children 15). Other cases, of lesser frequency, are the following: butterfly,—beauty; eagle,—flight; Bible,—truth; ocean,—depth; child,—innocence; and lion,—strength. Under the heading of pronouns (class XVIII), we have simply included every response consisting of a pronoun. The list of responses called non-specific (class XXI) has already been given in the earlier part of this chapter. Associations by sound-similarity (class XIX) in no case reach a frequency as high as 50, and in most cases have a frequency of only one or two. The following list of illustrations will suffice: table,—able; dark,—mark; short,—port; slow,—oh; wish,—mish; river,—sliver; red,—Ed; anger,—angry; high,—height; working,—work; city,—citizen; blue,—mew; stove,—love; stove,—move; and afraid,—maid.

CHAPTER VII

Comparison of Preferred Responses of Children and Adults

We have listed below the three most frequent responses of both children and adults. The results for the children are taken from our children's frequency tables and those for adults from the Kent-Rosanoff tables. The frequencies of the three commonest responses of each group are given in heavy faced figures. For each of these three highest frequencies of one group, are given the corresponding frequencies of the other group. For example, with the stimulus word *music,* the three commonest adult responses are *piano* (180), *sound* (95) and *song* (**68**), while the three commonest children's responses are *piano* (198), *sing* (153) and *sweet* (79). *Sound* and *song* are not among the children's three most frequent responses, but their frequency with children is given, for the sake of comparison, in plain type Similarly, the words *sing* and *sweet,* though not among the adults' three most frequent responses, have their frequency given in plain type. The table follows.

Comparison of Preferred Responses

Stimulus Word	Response Word	Frequencies	
		Adults	Children
1. Table	chair	**267**	16
	wood	**76**	21
	furniture	**75**	0
	eat	63	**358**
	dishes	40	**126**
	legs	10	**70**
2. Dark	light	**427**	38
	night	**221**	**421**
	black	**76**	**80**
	see	0	**57**
3. Music	piano	**180**	**198**
	sound	**95**	35
	song	**68**	50
	sing	12	**153**
	sweet	47	**79**
4. Sickness	health	**142**	6
	death	**115**	8
	illness	**71**	5
	doctor	62	**116**
	bed	54	**105**
	ill	48	**95**
5. Man	woman	**394**	8
	male	**90**	8
	boy	**44**	29
	work	17	**168**
	hat	7	**82**
	person	30	**45**
6. Deep	shallow	**180**	6
	water	**134**	**145**
	ocean	**93**	15
	hole	32	**257**
	well	44	**87**
7. Soft	hard	**365**	27
	pillow	**53**	**138**
	easy	**34**	15
	bed	12	**57**
	cotton	28	**57**
8. Eating	food	**170**	**54**
	drinking	**166**	2
	bread	**46**	**178**
	table	21	**168**
9. Mountain	high	**246**	**390**
	hill	**184**	**91**
	valley	**90**	3
	snow	10	**61**

Stimulus	Response	Frequencies	
Word	Word	Adults	Children
10. House	home	103	39
	building	78	16
	barn	74	12
	live	33	165
	warm	3	62
	big	4	51
11. Black	white	339	27
	dark	172	315
	color	129	104
	dress	29	63
14. Hand	foot	204	0
	fingers	88	130
	arm	68	44
	work	49	113
	clock	1	65
15. Short	long	279	54
	tall	108	12
	small	136	214
	little	15	157
16. Fruit	apple	157	131
	apples	102	174
	vegetable	75	10
	eat	62	153
17. Butterfly	insect	261	66
	bird	64	57
	fly	44	179
	wings	31	114
	pretty	39	89
18. Smooth	rough	277	35
	soft	79	132
	glass	56	48
	even	30	70
	nice	4	68
20. Chair	table	191	29
	seat	127	131
	sit	107	430
	set	0	38
21. Sweet	sour	301	23
	sugar	224	178
	candy	82	146
	good	26	213
22. Whistle	noise	173	185
	sound	103	18
	blow	95	189
	boy	56	79
23. Woman	man	292	17
	female	184	9
	girl	59	17
	lady	41	243
	dress	28	96
	mother	30	53
24. Cold	warm	166	25
	hot	151	12
	winter	120	108
	ice	114	84
	freeze	7	68
25. Slow	fast	316	65
	easy	68	13
	snail	62	2
	lazy	28	138
	walk	8	107

Stimulus	Response	Frequencies	
Word	Word	Adults	Children
26. Wish	desire	197	4
	want	66	90
	hope	51	10
	bone	0	55
	fairy	19	64
27. River	water	393	433
	stream	117	30
	lake	65	42
	swim	4	72
28. White	black	308	28
	color	170	116
	snow	91	65
	dress	34	149
	light	51	125
29. Beautiful	pretty	113	280
	handsome	86	13
	nice	73	169
	lady	5	38
30. Window	glass	316	421
	light	186	47
	pane	82	62
	look	15	116
31. Rough	smooth	346	35
	hard	38	144
	uneven	38	13
	boy	4	89
	mean	1	71
33. Foot	hand	185	5
	shoe	146	73
	walk	106	205
	toes	41	81
	leg	54	79
34. Spider	insect	276	57
	web	188	261
	fly	138	40
	legs	27	107
	bug	58	83
35. Needle	thread	160	72
	sharp	152	56
	pin	147	36
	sow	134	449
	sewing	107	81
36. Red	color	254	298
	blue	90	9
	white	97	18
	dress	18	85
	bright	40	66
37. Sleep	rest	300	40
	awake	94	14
	bed	75	351
	night	49	95
	tired	26	67
38. Anger	temper	149	8
	mad	121	471
	wrath	52	0
	cross	44	56
	fight	8	57
39. Carpet	floor	256	149
	rug	163	245
	soft	78	28
	walk	15	88
40. Girl	boy	350	46
	female	77	22
	woman	61	8
	dress	8	240
	child	49	45

Stimulus	Response	Frequencies	
Word	Word	Adults	Children
41. High	low	**328**	25
	mountain	**157**	**120**
	tall	**57**	56
	hill	20	**92**
	up	26	**60**
42. Working	labor	**147**	18
	hard	**105**	**290**
	busy	**51**	49
	man	50	**93**
	men	6	**51**
43. Sour	sweet	**349**	**75**
	vinegar	**91**	53
	lemon	**78**	57
	milk	31	**124**
	pickles	26	89
44. Earth	ground	**166**	**228**
	dirt	**115**	**102**
	clay	**71**	0
	round	61	**82**
46. Soldier	man	**189**	95
	army	**137**	63
	war	**94**	**203**
	fight	17	**160**
47. Cabbage	vegetable	**394**	**140**
	plant	**48**	27
	green	**44**	21
	eat	30	**193**
	leaves	11	**62**
48. Hard	soft	**367**	65
	stone	**102**	**118**
	wood	**66**	30
	rock	38	**92**
	work	19	**89**
49. Eagle	bird	**568**	**373**
	fly	**46**	**120**
	flying	**23**	10
	wings	16	**49**
50. Stomach	food	**102**	82
	body	**99**	78
	organ	**81**	0
	ache	31	**189**
	eat	45	**108**
	sick	10	**85**
51. Stem	flower	**259**	**367**
	leaf	**96**	11
	plant	**74**	25
	flowers	7	**80**
	long	18	**60**
52. Lamp	light	**650**	**648**
	oil	**49**	38
	chimney	**37**	18
	burn	20	**70**
	glass	8	**50**
53. Dream	sleep	**339**	**272**
	vision	**48**	4
	night	**42**	**260**
	bed	11	**78**
54. Yellow	color	**301**	**320**
	white	**70**	5
	orange	**47**	81
	dress	9	**129**
	flower	38	**105**

Stimulus	Response	Frequencies	
Word	Word	Adults	Children
55. Bread	food	**191**	37
	butter	**151**	68
	eat	**148**	**356**
	flour	88	**95**
	good	21	**90**
57. Boy	girl	**319**	32
	man	**104**	**61**
	child	**86**	45
	play	20	**84**
	pants	6	**63**
58. Light	dark	**231**	**99**
	darkness	**93**	0
	sun	**85**	29
	lamp	82	**251**
	bright	47	**74**
60. Bible	book	**338**	**224**
	religion	**89**	4
	holy	**57**	68
	God	43	**124**
	read	31	**116**
62. Sheep	animal	**225**	**117**
	lamb	**151**	**79**
	wool	**143**	**411**
63. Bath	water	**339**	**295**
	clean	**120**	**192**
	cleanliness	**109**	1
	wash	102	**143**
64. Cottage	house	**461**	**425**
	home	**85**	**101**
	country	**36**	6
	lake	5	**117**
65. Swift	fast	**222**	**391**
	slow	**190**	28
	quick	**117**	10
	run	19	**202**
	horse	28	**124**
66. Blue	color	**256**	**318**
	sky	**239**	**102**
	green	**54**	1
	dress	**18**	**173**
67. Hungry	food	**136**	**55**
	eat	**126**	**337**
	eating	**64**	5
	bread	26	**173**
68. Priest	minister	**178**	**168**
	church	**166**	**271**
	clergyman	**62**	0
	Catholic	36	**111**
69. Ocean	water	**427**	**413**
	deep	**87**	23
	sea	**75**	**88**
	waves	45	**88**
70. Head	hair	**159**	**203**
	body	**146**	26
	foot	**64**	0
	brains	32	**187**
	eyes	10	**91**
71. Stove	fire	**217**	**164**
	heat	**218**	117
	hot	**86**	**260**
	warm	32	**127**

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The preceding table shows in a striking manner how dissimilar are responses given by children from those given by adults. Only for 39% of the stimulus words is the most frequent response the same for both adults and children. Only for five stimulus words are the three most frequent adult responses also the three most frequent child responses. These stimulus words, with their responses, are sheep (animal, lamb, wool), thirsty (water, dry, drink), thief (steal, robber, burglar), scissors (cut, sharp, cutting) and blossom (flower, flowers, apple).

It may be observed that the response given most frequently by the adults is less apt to be one of the three most frequent children's responses than is a response given most frequently by the children to be one of the three most frequent of the adults' responses. The favorite adult reaction is one of the three most frequent of the children's in 59 per cent of the cases, while the children's favorite reaction is one of the adults' three most frequent in 74 per cent of the cases. Now it is shown in Chapter VIII that there are more adult responses not given by children than there are children's responses not given by adults. We may consequently conclude that the adult responses differ from children's not so much because of the dropping off of the children's responses as by the occurrence of additional responses. Of course the occurrence of additional responses causes a decrease in the percentage of the child responses given by adults. The range of adult responses is, however, broader than that of the children's. The adults retain what the children have and acquire much more besides.

It is of interest to note, further, how the absolute frequencies of the three preferred reactions of adults and children compare with each other. The average frequency of the favorite adult reaction is 264 (median 252), of the favorite children's reaction 270 (median 251). The number of adults' frequencies over 400 is 7, and of children's, 16. The number of adult frequencies over 300 is 34, and of children's, 36. The percentage of the entire 90,000 responses included by the three most frequent words is, for adults, 46% and for children, 48%. It is evident, then, that, with the list of stimulus words here used, there is not much difference between children and adults in the average frequency of the favorite reaction. This result is very interesting when compared, with the findings of Saling, Reinhold and Römer.[1]

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[1] See Chap. II, pp. 10-13 and 20-21.

CHAPTER VIII

INDIVIDUAL RESPONSES AND TOTAL NUMBER OF RESPONSE WORDS

The tendency of children, as compared with adults, to give individual responses has not hitherto been properly set forth. We will show that previous experimenters have not succeeded in reaching a general answer to the question whether children give more individual responses than adults. With the list of stimulus words we have used, children give decidedly fewer individual associations than adults.

A great deal of misunderstanding must exist regarding this matter, as nearly all experimenters (Ziehen, Wreschner, Saling, Reinhold and the Rosanoffs) have been cited to the effect that children give distinctly fewer common associations (and hence more individual association) than adults.[1] That the work of these experimenters has been incorrectly interpreted, we believe can be easily pointed out.

In the first place, Ziehen did not draw any conclusion concerning common and individual associations. He could not, because to do so requires frequency tables, and Ziehen had no frequency tables. It is true that Ziehen concluded that the commonest effect of the stimulus word in children is to call up an individual representation (Individualvorstellung). But the term, individual, as here used by Ziehen, is far from meaning an association not given by others. It means a concrete image as contrasted with a general idea.

Considering next the work of Wreschner, we have simply to observe that conclusions concerning the tendency of children to give individual associations, a matter which has to be determined statistically, can not very safely be drawn from an investigation employing but 2 subjects, both under 6 years of age.

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[1] See Whipple G. M., 'Manual of Physical and Mental Tests,' 2d Ed., Part II, 1915, p. 60.

Saling did not consider the matter of individual associations, but made merely a comparison of children and adults with respect to the frequency of the favorite, or most frequent, reaction.[2]

Reinhold, like Saling, did not consider the matter of individual associations, but merely the variation with age in the average frequency of the favorite response. On this point his data are materially different from those of Saling.[3] If it be said that these investigators show that the most frequent reaction has a higher frequency with adults than with children, and that *consequently* children must be supposed to give a larger number of individual associations, we can only ask, who has shown this? Our own data, and, on this point, there are no other at hand, show no such relation between the frequency of preferred responses and the total number of responses. We find the average frequency of the most frequent response to be very nearly the same in both children and adults whereas we find that adults give a decidedly larger number of individual associations.

We come, lastly, to the investigation made by the Rosanoffs. What the Rosanoffs actually showed is that younger children give a larger percentage of responses not found in the Kent-Rosanoff adult tables than do the older children. This conclusion should not be misleadingly stated by saying simply that children give more individual associations than adults. That children would give adult responses less often than adults seems clear. When, however, one says that children give more individual associations than adults, he implies that they give more responses with a frequency of only one. This is not the case, as will be seen below.

In order, now, to show the tendency of children, as compared with adults, to give individual associations, we give merely the number of associations in both the children and adult tables with a frequency of one. With children, we take as individual responses, those which have a frequency of only one in our children's (written) frequency tables. With adults, we take as individual responses, those with a frequency of one in the Kent-Rosanoff tables. This means we follow the same procedure with both children and adults that Kent and Rosanoff do in the case of adults. We shall not, however, make any distinction between 'doubtful'[4] reactions and individual reactions. We define as an individual association, then, any response occurring only once in a frequency table of 1,000 responses. This is a technical definition. Broadly speaking, we regard as an individual association any association not commonly given by persons of the class in question. In order to get figures, it is necessary to agree on some standard for determining whether an association is commonly given. We arbitrarily agree to call uncommon an association found only once in a thousand cases.

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[2] See Chapter II, p. 10, 11.

[3] See Chapter II, p. 13.

The figures on individual associations, as defined above, for both adults and children, are given in the accompanying table.

INDIVIDUAL RESPONSES, NINETY STIMULUS WORDS

Stimulus	Children	Adults	Stimulus	Children	Adults
1. Table	49	66	51. Stem	69	57
2. Dark	50	70	52. Lamp	37	39
3. Music	45	92	53. Dream	77	117
4. Sickness	54	81	54. Yellow	66	79
5. Man	59	111	55. Bread	46	52
6. Deep	49	70	57. Boy	85	105
7. Soft	64	79	58. Light	62	84
8. Eating	46	82	60. Bible	38	63
9. Mountain	52	82	62. Sheep	64	62
10. House	55	96	63. Bath	39	46
11. Black	49	62	64. Cottage	48	75
14. Hand	65	80	65. Swift	51	77
15. Short	75	101	66. Blue	64	65
16. Fruit	23	61	67. Hungry	87	92
17. Butterfly	29	77	68. Priest	54	91
18. Smooth	41	91	69. Ocean	40	58
20. Chair	24	54	70. Head	62	84
21. Sweet	35	55	71. Stove	30	44
22. Whistle	45	84	72. Long	95	116
23. Woman	54	89		41	94
24. Cold	51	70	74. Whiskey	73	91
25. Slow	30	131	75. Child	46	51
26. Wish	44	144	77. Hammer	28	47
27. River	23	75	78. Thirsty	53	78
28. White	76	79	79. City	67	105
29. Beautiful	33	109	80. Square	32	48
30. Window	48	52	81. Butter	39	98
31. Rough	68	121	82. Doctor	72	75
33. Foot	68	69	83. Loud	50	98
34. Spider	56	77	84. Thief	48	81
35. Needle	24	35	85. Lion	47	104
36. Red	65	70	86. Joy	31	54
37. Sleep	67	71	87. Red	63	100
38. Anger	68	175	88. Heavy	32	70
39. Carpet	56	62	89. Tobacco	54	85
40. Girl	55	104	90. Baby	33	58
41. High	72	61	91. Moon	23	49
42. Working	70	122	92. Scissors	53	100
43. Sour	53	50	93. Quiet	58	65
44. Earth	59	80	94. Green	60	80
46. Soldier	48	88	95. Salt	62	89
47. Cabbage	36	58	96. Street	84	72
48. Hard	67	93	97. King	32	75
49. Eagle	49	53	98. Cheese	69	57
50. Stomach	70	84	99. Blossom	39	52
			100. Afraid	49	124

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[4] Kent and Rosanoff classify as 'doubtful' any response which occurs only once, but it is a grammatical variant of some other obtained response.

SUMMARY

	Children	Adults
Total number	4,702	7,171
Per Cent of all Responses	5.2	8.0
Av. per Stim. Word	52	80
Median per Stim. Word	50	79

In the case of only five words, does the number of individual responses given by the children exceed that given by the adults. These five words are ***high***, ***sour***, ***stem***, ***sheep***, and ***king***. The largest number of individual responses given by the children is 95, to the word *long*. The largest number given by the adults is 175, to ***anger***. The adults give over 95 individual responses to each of 20 words. For 92 per cent of the words, the number of individual responses for the adults exceeds the median number for the children. It is clear, then, that children give decidedly fewer individual associations than adults.

Besides the percentage of individual responses, that is, of responses of a frequency of one, it is of interest to note the percentage of responses of other frequencies. This is shown in the following table, which gives the percentage of the total number of responses, made up by responses of various specified frequencies.

PERCENTAGES (OF ALL RESPONSES) COMPOSED BY RESPONSES OF VARIOUS FREQUENCIES

Frequency	Percentage of all Responses Children	Adults
1	5.2	8.0
2—9 incl	12.4	13.6
10—99 "	39.3	37.7
100—199 "	16.8	16.0
200—299 "	10.1	10.7
300—399 "	7.7	10.2
400 or over	8.5	3.8

In this connection, it is interesting to note that adults give more of the children's responses than do children of the adults' responses. To show this, we have determined, first, the number of responses given by adults not occurring in our children's frequency tables (written responses) and, second, the number of responses given by children not occurring in the Kent-Rosanoff tables. The adults give 8,847 words which do not occur in our children's frequency tables. These words have a combined or total frequency of 19,742. The children, on the other hand, give only 5,253 words not occurring in the Kent-Rosanoff tables. The total frequency of these words is 12,510. These results are in accord with the general fact, already noted in another connection,[8] that the adults tend to keep the children's responses, while acquiring new ones. This is what we should expect, since evidently all the children's responses are responses which adults could give and would give occasionally, whereas a great many of the adult responses involve associations that are hardly possible for the child, if for no other reason, on account of his limited experience and speech endowment. The adults' experience *includes* the child's experience.

Lastly, we may consider the total number of different response words given. The data are given in the accompanying table.

TOTAL NUMBER OF RESPONSE WORDS, NINETY STIMULUS WORDS

Stimulus	Children	Adults
1. Table	104	124
2. Dark	104	114
3. Music	84	172
4. Sickness	123	145
5. Man	150	169
6. Deep	112	119
7. Soft	163	155
8. Eating	127	168
9. Mountain	103	142
10. House	144	184
11. Black	112	109
14. Hand	148	146
15. Short	138	159
16. Fruit	70	123
17. Butterfly	81	145
18. Smooth	116	157
20. Chair	77	107
21. Sweet	82	95
22. Whistle	114	151
23. Woman	129	163
24. Cold	118	123
25. Slow	128	204
26. Wish	106	232
27. River	73	127
28. White	125	135
29. Beautiful	110	182
30. Window	88	102
31. Rough	156	201
33. Foot	112	127
34. Spider	105	126
35. Needle	61	72
36. Red	112	138
37. Sleep	105	129
38. Anger	99	281
39. Carpet	106	135
40. Girl	123	169
41. High	130	120
42. Working	127	221
43. Sour	89	91
44. Earth	109	162
46. Soldier	91	159
47. Cabbage	80	126
48. Hard	110	156
49. Eagle	89	109
50. Stomach	123	162
51. Stem	103	120
52. Lamp	63	78
53. Dream	125	185
54. Yellow	104	149
55. Bread	83	104
57. Boy	159	174
58. Light	117	142
60. Bible	91	128
62. Sheep	106	110
63. Bath	71	93
64. Cottage	80	142
65. Swift	89	127
66. Blue	108	116
67. Hungry	136	173
68. Priest	92	161
69. Ocean	69	110
70. Head	115	163
71. Stove	57	91
72. Long	178	178
74. Whiskey	71	152
75. Child	115	162
77. Hammer	76	109
78. Thirsty	52	86
79. City	109	131
80. Square	122	195
81. Butter	58	101
82. Doctor	68	151
83. Loud	115	140
84. Thief	86	170
85. Lion	93	137
86. Joy	88	172
87. Bed	72	112
88. Heavy	109	158
89. Tobacco	64	122
90. Baby	104	150
91. Moon	75	110
92. Scissors	36	181
93. Quiet	96	167
94. Green	96	122
95. Salt	107	146
96. Street	119	163
97. King	135	120
98. Cheese	60	146
99. Blossom	63	99
100. Afraid	92	189

SUMMARY

	Children	Adults
Total Number	9,183	12,871
Average per Stimulus Word	102	143
Median " " "	105	142

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[8] See Chapter VII, p. 97.

The total number of response words is greater with adults in the case of all but 6 stimulus words. These 6 stimulus words are *soft, black, hand, high, long* and *king*. They each have an opposite or coordinate similar to an opposite (as hand,—foot and king,—queen) which, in accordance with the general rule, absorbs a much larger portion of the adults' responses than of the children's. The largest array of responses given by the children occurs with the word *long*, to which they give 178 responses, whereas the adults give as high as 281 responses to the word *anger*, and give over 200 responses to each 5 words. For 89 per cent of the stimulus words, the number of responses given by the adults is larger than the median number given by the children. Of the 12,871 adults' response words, 8,847, or 69 per cent, are not given by the children; while of the 9,183 children's response words, 5,253, or 57 per cent, are not given by adults.

CHAPTER IX

COMPARISON OF ORAL AND WRITTEN RESPONSES

Since the Kent-Rosanoff data were obtained orally, while ours were obtained in writing, it seemed desirable to check up our data with results obtained orally. This we did, as already explained, in the case of the first 9 words. We find that the written and oral results, taken as a whole, are essentially similar. Since the 9 words used constitute a fair sample of the whole list, it may be presumed that our results are valid no matter which method is used.

In the preceding chapters, we have drawn conclusions concerning the differences between children and adults on the following points:

1. The frequencies of various association types.
2. Preferred reactions and their frequencies.
3. Individual responses and the total number of response words.

We shall proceed to compare, on each of these points, the responses obtained orally and those obtained in writing. By putting the Kent-Rosanoff data on adults alongside our data on children, we will show that every conclusion we have drawn holds for the children's oral responses as well as for their written ones.

1. The Frequency of Various Association Types.—We give below the total number of associations of each type obtained in response to the first 9 stimulus words. In the first column, is given the number of children's written responses, in the second, the number of children's oral responses and in the third, the number of adults' responses. That the 9 words here considered are fairly representative of the total results, is shown by the fact that for most types the ratios between children and adults are roughly the same for the 9 words as for the total results.

TOTAL FREQUENCIES OF VARIOUS ASSOCIATION TYPES

NINE STIMULUS WORDS

	Association Type	Children Written	Children Oral	Adults (Oral)
Preferred by Adults	Contrast	143	282	1,680
	Noun-Abst. Att.	15	0	73
	Part-Whole	0	0	0
	Superordination	96	102	352
	Participles	93	133	360
	Coordination	271	356	564
	Cause-Effect	136	138	313
Preferred by Children	Verbs	1,037	1,058	136
	Verb-Object	463	453	296
	Noun-Adj.	838	818	420
	Adj.-Noun	1,093	1,075	715
	Contiguity	1,381	1,281	581
	Whole-Part	203	211	158
	Subordination	533	415	333
	Pronouns	30	35	1
	Sound Similarity	86	76	4
	Word Compounding	105	100	109
Equally Frequent in Both Groups	Similarity	360	406	563
	Effect-Cause	44	39	91
	Material	33	26	78
	Non-Specific	748	737	595
	Miscellaneous	15	10	1

The agreement between the children's oral data and their written data is so close that there can be little question but that all our conclusions would hold as well for the one as for the other. It is interesting to note, however, that orally the children give nearly twice as many associations by contrast and also more coordinates and more participles than they do in writing. They seem, further, to give fewer subordinates and fewer associations of the class verb-object. These differences may not be reliable, but they seem sufficiently marked to suggest that somehow they are correlated with the difference in method. Just why children should give opposites orally more frequently than in writing is hard to say. It can hardly be due to any difficulty in writing, since many words which are written infrequently as opposites are written very frequently when they form associations of some type more characteristic of children. This whole matter of the difference between the mental attitudes in writing and speaking should be made the object of a special investigation. The results here obtained suggest one method.

2. Preferred Reactions and Their Frequencies.—In the adjoining table, will be found the three most common reactions for each of the nine stimulus words used orally.

THREE MOST FREQUENT RESPONSES

		Children		Adults
	Stimulus	Written	Oral	(Oral)
1.	Table	358 eat	331 eat	267 chair
		126 dishes	115 dishes	76 wood
		70 legs	56 legs	75 furniture
2.	Dark	421 night	410 night	427 light
		80 black	100 black	221 night
		57 see	98 light	76 black
3.	Music	198 piano	236 sing	180 piano
		153 sing	166 piano	95 sound
		79 sweet	66 notes	68 song
4.	Sickness	116 doctor	131 bed	142 health
		105 bed	116 doctor	115 death
		95 ill	94 ill	71 illness
5.	Man	168 work	153 work	394 woman
		82 hat	68 hat	99 male
		45 person	57 big	44 boy
6.	Deep	257 hole	244 hole	180 shallow
		145 water	162 water	134 water
		87 well	76 well	93 ocean
7.	Soft	138 pillow	122 pillow	365 hard
		57 bed	71 cushion	53 pillow
		57 cotton	65 cotton	34 easy
8.	Eating	178 bread	152 bread	170 food
		108 table	113 table	166 drinking
		54 food	103 food	46 bread
9.	Mountain	390 high	432 high	246 high
		91 hill	104 hill	184 hill
		61 snow	50 climb	90 valley

The table shows that the dissimilarity between the preferred responses of children and adults is as striking with the children's oral responses as with their written. The average frequency of the children's most frequent response is 246 with the oral data, and 247 with the written data. The total frequency for the three preferred responses for all nine stimulus words is 3,891 with the children's oral results, and 3,776 with the written. With such close agreement between the oral and written data in the preferred responses and their frequencies, it is clear that any conclusions on these points hold equally well for oral and for written data.

3. Individual Responses and Total Number of Response Words.—The total number of response words given to a stimulus word is, on the average, exactly the same for the written and for the oral data, and the number of individual responses is nearly the same. Our conclusion that adults give more individual responses and also a larger total number of response words than children evidently holds for the oral data as well as for the written. The figures are as follows:

	NUMBER OF INDIVIDUAL RESPONSES			TOTAL NUMBER OF RESPONSE WORDS		
Stimulus	Children		Adults	Children		Adults
Word	Written	Oral	(Oral)	Written	Oral	(Oral)
1. Table	49	47	66	104	103	124
2. Dark	50	59	70	104	113	114
3. Music	45	47	92	84	102	172
4. Sickness	54	53	81	123	110	145
5. Man	59	75	111	150	161	169
6. Deep	49	57	70	112	107	119
7. Soft	64	77	79	163	160	155
8. Eating	46	39	82	127	112	168
9. Mountain	52	51	82	103	100	142
Total Number	468	505	733	1,070	1,068	1,308
Av. per Stimulus Word	52	56	81	119	119	145

CHAPTER X

GENERAL SUMMARY

The present work contains children's association frequency tables for each of 100 stimulus words. The tables are composed of the responses of 1,000 Minneapolis school children, from 9 to 12 years of age inclusive, all in the fourth and fifth grades.

The list of stimulus words contains 90 words of the Kent-Rosanoff list. A comparison is made in the case of these 90 words between the children's associations and the associations of adults as shown by the Kent-Rosanoff tables.

The chief points established by this comparison may be stated as follows:

1. In general, children's associations differ enormously from those of adults.

2. Marked differences exist between children and adults in the frequency of various types of association. The types which occur more frequently with adults than with children are the following: contrast, superordination, coordination, part-whole, noun-abstract attribute, participles and cause-effect. The types which occur more frequently in children than adults are the following: verbs, verb-object, noun-adjective, adjective-noun, pronouns, sound similarity, contiguity, whole-part and, less definitely, subordination and word-compounding. No reliable difference was found between the groups witih respect to the following types: similarity (in meaning), material, effect-cause, non-specific reactions and a miscellaneous group. The results concerning associations of the class, effect-cause, are not regarded as very reliable.

3. With only 39 per cent of the stimulus words, is the most frequent response the same for both children and adults. Only with five words, are the three most frequent responses the same for both children and adults.

4. The frequency of the favorite, or most frequent response,

is about the same for both groups, as is also that of the three most frequent responses. Thus the medium frequency of the favorite response is 251 for children and 252 for adults, while the percentage of all responses included by the three preferred responses is 48 for children and 46 for adults.

5. Children give fewer individual responses than adults. Defining as individual responses, those with a frequency of only one in the frequency tables, it may be said that, on the average, children give only fifty-two individual responses to a stimulus word, whereas adults give eighty.

6. The number of different words given in response to any stimulus word is less with children than with adults, being, on the average, 102 with children and 143 with adults.

7. The adults give more of the children's response words than the children do of the adults'. Thus, the adults give 8,847 words not given by the children. These words have a combined frequency of 19,742. The children, on the other hand, give only 5,253 words not given by the adults. Their combined frequency is 12,510. Moreover, in the case of any stimulus word, the children's favorite response is more apt to be given frequently by adults than is the adults' favorite response to be given frequently by children. Thus, the favorite adult response is one of the children's three most frequent in 59 per cent of the cases while the children's favorite response is one of the adult's three most frequent in 74 per cent.

The preceding conclusions have general validity only in so far as the list of stimulus words used can be called representative. They are not dependent upon the manner in which the responses are given, since they hold as well for oral responses as for written. They hold likewise for children of each of the four age groups used, since the differences with age found in the children is slight as compared with the differences between children and adults.

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